M.S.

Eisenhower Consortium Bulletin 8

The Eisenhower Consortium for Western Environmental Forestry Research: Research Highlights, 1972-1980

Gordon D. Lewis, Compiler

Eisenhower Consortium for Western Environmental Forestry Research

Publications of the Eisenhower Consortium

Bulletins:[1]

Eisenhower Consortium for Western Environmental Forestry Research. 1975. Man, leisure, and wildlands: A complex interaction. Proceedings of the first Eisenhower Consortium Research Symposium, September 14-19, 1975, Vail, Colo. Eisenhower Consortium Bulletin 1, 286 p. Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, Colo. PB 248417

Aukerman, Robert, and William T. Springer. 1976. Effects of recreation on water quality in wildlands. Eisenhower Consortium Bulletin 2, 25 p. [Colorado State University] Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, Colo. PB 251104

Segall, Burton A. 1976. The impact of vacation homes on national forest water resources. Eisenhower Consortium Bulletin 3, 19 p. [Arizona State University] Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, Colo. PB 253732

Fechner, Gilbert H., and Jack S. Barrows. 1976. Aspen stands as wildfire fuel breaks. Eisenhower Consortium Bulletin 4, 26 p. [Colorado State University] Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, Colo. PB 255063

Ostheimer, John M. 1977. The Forest Service meets the public: Decisionmaking and public involvement on the Coconino National Forest. Eisenhower Consortium Bulletin 5, 24 p. [Northern Arizona University] Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, Colo. PB 267094

Hasfurther, Victor R., and David H. Foster. 1978. Operation and design of evapotranspiration waste disposal systems. Eisenhower Consortium Bulletin 6, 21 p. [University of Wyoming] Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, Colo.

Fisher, Carla J., and Charles D. Ziebell. 1980. Effects of watershed use on water quality and fisheries in an Arizona mountain lake. Eisenhower Consortium Bulletin 7, 8 p. [University of Arizona] Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, Colo.

Institutional Series:[2]

Bond, M. E., and R. H. Dunikoski. 1977. The impact of second-home development on water availability in north central Arizona. Eisenhower Consortium Institutional Series Report 1, 88 p. Bureau of Business and Economic Research, Arizona State University, Tempe.

Hogan, Timothy D. 1977. Second-home ownership in northern Arizona: A profile and implications for the future. Eisenhower Consortium Institutional Series Report 2, 113 p. Bureau of Business and Economic Research, Arizona State University, Tempe.

Lee, Robert W., Ralph H. Ramsey III, and Lloyd V. Urban. 1978. Environmental guidelines for second home developments in mountain areas. Eisenhower Consortium Institutional Series Report 3, 125 p. Water Resources Center, Texas Tech University, Lubbock.

Hogan, Timothy D., M. E. Bond, and Robert H. Dunikoski. 1979. Streamflow and second-home development in northern Arizona. Eisenhower Consortium Institutional Series Report 4, 71 p. Bureau of Business and Economic Research, Arizona State University, Tempe.

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[1] Brackets indicate university affiliation of bulletin authors. PB numbers indicate the initial printing at the Rocky Mountain Station has been exhausted, and copies are now available only from the National Technical Information Service, 5825 Port Royal Road, Springfield, VA 22161. Copies are on file, however, at most university and other major libraries.

[2] Copies of Institutional Series Reports are available only from the originating university.

The Eisenhower Consortium for Western Environmental Forestry Research: Research Highlights, 1972-1980[1]

Compiled by Gordon D. Lewis[2].

[1]*The research reported here was supported in part by the Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, through the Eisenhower Consortium for Western Environmental Forestry Research.*

[2]*Program Manager, Western Environmental Forestry Research Program, Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, Colo.*

Abstract

Lewis, Gordon D., compiler. 1980. The Eisenhower Consortium for Western Environmental Forestry Research: Research highlights, 1972-1980. Eisenhower Consortium Bulletin 8, 31 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Presents brief summaries of final reports submitted upon completion of research agreements with the 9 Consortium universities. Research emphasizes relationships between human recreational activities and natural environments. Summaries are organized under topics of air quality, water quality, watershed management, wildlife, social and economic effects, management activities, and fire.

Foreword

The Eisenhower Consortium for Western Environmental Forestry Research was established in 1972 to expand university and USDA Forest Service research capabilities to meet the new challenges created by population growth and increasing recreational use of wildlands. The Consortium pools USDA Forest Service research talent with that of nine western universities to form a base from which expertise can be drawn to find solutions to the most pressing man-environment problems.

This research emphasizes relationships between human recreational activities and the natural open-space environments. The nine member universities--the Universities of Wyoming, Colorado, Arizona, and New Mexico; and Colorado State, Northern Arizona, Arizona State, New Mexico State, and Texas Tech Universities--have usually undertaken their research within their states. However, with few exceptions, the results are indicative of what is happening elsewhere, and recommendations for corrective actions are usually applicable throughout the Rocky Mountains and adjacent High Plains.

USDA Forest Service research conducted by Consortium member universities covers many aspects of human impacts on open-space environments. The studies have involved a number of talents on a number of problems in a number of geographical areas. As a result, the research abstracts in this report have been organized by subject matter categories.

The Consortium research program is recreation oriented, and the results reported here relate, directly or indirectly, to either the effects of recreation or recreation management activities on the natural environment or the effects of environmental conditions on the potential for recreation.

The purpose of this publication is to present abstracts of the results of studies undertaken and completed during the period 1972 through 1979. Results of some studies have been reported in Eisenhower Consortium bulletins, Rocky Mountain Station research papers, university or other organizational publications, or technical journals; others have not been published. It is hoped that the brief statements in this bulletin will provide direction to interested researchers and land managers in finding more detailed information they need.

Additional material and complete reports are often available from the principal investigators at the individual universities, and from the library of the Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, CO 80526. The Rocky Mountain Station library can provide some materials through direct loans or interlibrary loans on request. Eisenhower Consortium bulletins that have gone out of print can be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Request items by the PB number listed at the end of the citations inside the front cover of this bulletin.

Contents

I. Air Quality

Beach, Jeff, and W. E. Marlatt. I-1
1979. Atmospheric carrying capacity of the Gunnison Valley, Colorado. 112 p. including two appendices.

The results of the ambient air quality analysis have shown that through the year 1990, federal and/or state ambient air quality standards will probably not be violated in the Gunnison Valley airshed. The first standard likely to be broken will be the state standard for total suspended particulates (TSP) when the population in the airshed reaches approximately 36,000 people. Emissions from fireplaces were found to be the major source of particulate pollution in the Gunnison Valley airshed in 1978, and the concentration from this source produces about 93% of the total TSP emissions considered in 1990. Mobile sources may also contribute significant amounts of particulate matter to the airshed. Spaceheating produces a negligible amount of particulate matter.

Under the worst case conditions, calculated concentrations of total suspended particulates over the entire valley were 30 $\mu g/m^3$, while in the downtown areas of the two communities, worst case days in 1978 had concentrations of 200 $\mu g/m^3$ and more. To avoid concentrated air pollution problems in the future, it is recommended that population growth in the airshed be spread out and dispersed rather than concentrating it in and around the communities.

Research Agreement 16-806-GR
Colorado State University
William E. Marlatt, Principal Investigator

Berman, Neil S. I-2
1975. Air pollution potential in Arizona. 40 p. plus 3 appendices with supplement.

Background and urban levels of present air quality are presented for reference. Wind speeds and mixing heights, the important parameters in air pollution potential, are discussed for the state. Frequencies of wind direction and average velocities are used in Gaussian plume models to evaluate air pollution potential at several locations in the state. Detailed airshed modeling to give spatial and temporal distributions of atmospheric concentrations are discussed for the Salt River Valley, the location of Phoenix, Ariz.

In general, the lower wind speeds in the southwestern desert areas of the state lead to higher predicted yearly average concentrations of potential pollutants. However, the northeastern plateau has the highest frequency of prolonged low-level afternoon inversions. Normally, the air in Arizona is clean and visibility is extremely high. Small amounts of pollutants in the air can lead to discoloration and reduce visibility, although concentrations are far below air quality standards.

Maps of air pollution potential are presented in a separate supplement as overlays on U.S. Geological Survey maps. The use of these overlays for other locations in the state is discussed.

Research Agreement 16-463-CA
Arizona State University
Neil S. Berman, Principal Investigator

Published in part in Eisenhower Consortium Bulletin 1, p. 235-244.

Greenland, David. I-3
1979. A study of air pollution potential in mountain environments as a factor in locating resorts. 63 p. plus 5 appendices illustrated.

This research was undertaken to evaluate air quality maintenance in complex mountain areas where vacation resorts are often located. The report presents a review of basic approaches to estimating air quality in such complex terrain and results of using various methods of estimating mixing heights and valleys.

Long-term NWS Rawinsonde data give interesting results, but none that can be used operationally. Little success was met in seeking spatial relations in short-term inversion data. The most profitable approach seems to be in the use of a theoretical model of inversion rise dynamics. A box model of atmospheric dispersion is utilized in (1) a standard form, (2) with modeled mixing heights, and (3) with a tilted inversion lid. The latter does not significantly improve the performance of the basic model. However, there is evidence to suggest the flexibility of using modeled mixing height data with the box model. An interesting lag effect is noted for the model.

Some practical aspects with regard to air pollution potential and land management alternatives are discussed.

Research Agreement 16-805-GR
University of Colorado
David Greenland, Principal Investigator

Marlatt, William E., and Lawrence Krupnak. I-4
1976. Air pollution potential for selected areas in the Rocky Mountain West. 2 p.

Vector windfields were mapped and air pollution potential index delineated for national forests in Wyoming and the Black Hills National Forest in South Dakota. Original overlays as well as one set of 1:1 photoreproductions were made with legend for self-explanatory interpretations of the findings.

The Divergent Pollution Dispersion Index (DPDI) was subjectively categorized into regions defined as low, moderate, high, and extreme

pollution potential areas. The delineations should therefore be viewed as a highly respected qualitative first approximation of an area's pollution dispersion capabilities under a light (Beaufort Wind Force Number 0-1) northwest synoptic flow. Such a wind regime is predominate over the area, climatologically speaking, at a speed conducive for pollution episodes.

Research Agreement 16-470-CA
Colorado State University
William E. Marlatt, Principal Investigator

Published in part in Eisenhower Consortium Bulletin 1, p. 227-234.

Nash, Thomas H., III, Harold C. Fritts, and Marvin A. Stokes. I-5
1975. A technique for examining non-climatic variation in widths of annual tree-rings with special reference to air pollution. 18 p.

A new technique was developed for examining non-climatic variations in widths of annual tree rings. For each tree core, the technique involves making an adjustment for regional climate as inferred from a regional chronology based on surrounding sites. The technique is applied to two stands in Gila County, Arizona, where air pollution is potentially a limiting factor on tree-ring growth. For the stand closest to the pollution sources, a marked decrease in tree-ring width is evident during the period 1908 to 1920. Although this decrease coincides with a period when two smelters were operating nearby, air pollution cannot be definitively identified as the cause of the decrease in ring width size.

Research Agreement 16-446-CA
Arizona State University
Thomas H. Nash III, Principal Investigator

Published as Eisenhower Consortium Journal Series Paper 9 in The Tree-Ring Bulletin 35:15-24, 1975.

Wittmann, D. L., and M. J. Trlica. I-6
1975. Effects of nitrogen dioxide and ozone on photosynthesis and dark respiration of ponderosa pine. 15 p.

Ponderosa pine seedlings were exposed in an environmental chamber to nitrogen dioxide and ozone at concentrations of 0.00, 0.01, 0.10, and 1.00 p/m of each gas in 1-hour fumigations. One-hour exposures to ozone depressed photosynthetic rates, while nitrogen dioxide stimulated dark respiration rates. Combinations of nitrogen dioxide and ozone depressed photosynthetic rates and stimulated dark respiration rates, indicating a synergistic effect.

Research Agreement 16-469-CA
Colorado State University
Milton J. Trlica, Principal Investigator

II. Water Quality

Aukerman, Robert, and II-1
William T. Springer.
1978. Effects of recreation on water quality in wildlands. 66 p.

The findings of this study indicate that campers are not at present contributing significantly to water pollution. In fact, as concentrations of campers increase, bacterial pollution decreases. Inversely, as concentrations of campers decrease, water pollution increases. This suggests some interesting management practices, such as the concentration of campers. Comparisons of different types of campers (e.g., motorized, backpack, social oriented) indicate extreme differences in their contributions to pollution loads. For example, no pollution was observed from heavily used backpack camping areas, while the highest pollution loads were observed in nonconcentrated motorized camping areas. The findings from this study have been related to management practices in an effort to make them immediately applicable for recreation and water resource planners and managers.

Research Agreement 16-466-CA
Colorado State University
Robert Aukerman, Principal Investigator

Published as Eisenhower Consortium Bulletin 2, 25 p. 1976.

Bottorff, R. L., J. V. Ward, C. A. II-2
Carlson, C. Bobo, and D. N. McBride.
1976. Influence of highway construction on the recreational values of a high mountain stream. 95 p. illustrated.

Stream biota and physiochemical conditions in Joe Wright Creek were studied from June 9 to November 2, 1975, at five sampling stations adjacent to highway construction activities on the Roosevelt National Forest. Construction activities had no apparent effect on such parameters as pH, temperature, dissolved oxygen, or dissolved solids. Construction added fine particles to the substrate and increased suspended solids and organic detritus. Increased organic detritus may have been responsible for increased macroinvertebrate biomass. From limited sampling, it appears that the biomass of epilithic algae may have decreased as a result of construction activities.

Trout food consisted primarily of bottom-dwelling and terrestrial insects; no definite conclusions can be drawn regarding age and growth of fishes from the first year's data.

Research Agreement 16-522-CA
Colorado State University
James V. Ward, Principal Investigator

Brickler, Stanley K., and II-3
Gordon S. Lehman.
1973. Impact of recreation use on water quality in the White Mountains of Arizona. 19 p.

Water quality analyses were made on samples taken from three lakes in the White Mountains of Arizona during the period of greatest recreational use. Analyses included fecal coliform organism counts, nitrate and phosphate levels, water temperatures, and turbidity.

No real pollution problems existed on the three lakes, but the potential was there, and certain uses could have detrimental effects on water quality. The most serious problem appears to be the construction of summer homes with septic tank waste disposal systems around isolated areas of the lakes. The lower levels of water mixing increases the probability of having concentrations of fecal coliform organisms. Better management criteria are needed for construction of these facilities.

Research Agreement 16-281-CA
University of Arizona
Stanley K. Brickler, Principal Investigator

Published in Eisenhower Consortium Bulletin 1, p. 195-201. As: Brickler, Stanley K., and Jack G. Utter. Impact of recreation use and development on water quality in Arizona: An overview.

Brickler, Stanley K., and II-4
Jack G. Utter.
1975. Impact of recreation use on water quality in the White Mountains of Arizona. 142 p.

This report examines the relationship of water quality to recreation use in selected lakes and streams in the White Mountains of Arizona. Four major parameters of water quality were investigated: (1) physical environmental factors, (2) chemical nutrient concentrations, (3) fecal bacterial contaminations, and (4) visitor use effects.

The results indicate intensive recreational use and development may be reflected in decreased water quality. The sample lake exhibiting the greatest level of recreational use and development showed significantly greater fecal bacterial contamination in the concentrated use area.

The report outlines managerial considerations for assisting recreational land managers in recognizing and preventing present and future water quality problems.

Research Agreement 16-340-CA
University of Arizona
Stanley K. Brickler, Principal Investigator

Published in Eisenhower Consortium Bulletin 1, p. 195-201.

Cunningham, Karen K., and Milton R. Sommerfeld. II-5
1977. Influence of second-home development on stream water quality of Tonto Creek, Arizona. 116 p. with 31 tables and 29 figures.

Physio-chemical and bacteriological analyses of Tonto Creek, Arizona, were made from September 1976 through August 1977 to evaluate the effect of second-home development and heavy recreational use on stream water quality. Parameters investigated included temperature, turbidity, pH, alkalinity, dissolved oxygen, conductivity, ammonia nitrogen, nitrate nitrogen, orthophosphate phosphorus, total phosphate phosphorus, chloride, sulfate, silica, boron, sodium, calcium, magnesium, potassium, iron, zinc, chromium, copper, BOD, COD, and numbers of total coliforms, fecal coliforms, and fecal streptococci.

Monitoring revealed a well oxygenated, low turbidity stream that becomes increasingly mineralized with elevational descent, with appreciable downstream increases in specific conductance, calcium, sodium, magnesium, chloride, bicarbonate, sulfate, and silica. With the exception of calcium, sodium, chloride, and sulfate, the increase was gradual. These elements, in addition to a gradual increase, showed major increases between specific sites in lower Tonto. These increases do not appear to be associated with second-home development or recreational use, but result from springs or other geologic sources. Trace metal concentrations were consistently low. Nutrient (N and P) concentrations were high throughout the stream, even in the upper reaches where human activity is limited, suggesting the natural stream levels are relatively high. Biochemical and chemical oxygen demands indicated the creek was relatively clean.

Bacteriological determinations indicated the stream rarely exceeds water quality standards. Based on fecal coliform to fecal streptococci ratios, bacterial contamination of the stream is primarily from livestock and wildlife.

Tonto Creek appears to have acceptable water quality that is at the present not measurably influenced by the presence of second-home, resort, and heavy recreational use.

Research Agreement 16-643-GR
Arizona State University
Milton R. Sommerfeld, Principal Investigator

Currier, John B. II-6
1974. Water quality effects of logging residue decomposition from lodgepole pine. 152 p. with 25 tables and 35 figures (dissertation).

Chipped residue from a lodgepole pine clearcut was collected and leached in the laboratory. The major objective was to determine if the leached compounds would adversely affect water quality.

The leachate consisted primarily of carbohydrates, phenolics, and mineral salts. The carbohydrates were rapidly utilized by microbial organisms and removed from the solution; consequently, the leachate consisted primarily of phenolics, largely tannin. Mineral salts comprised approximately 15% of the extracted material.

Decomposition and percolation tests with the leachate showed that approximately 50% of the phenolics would decompose within 96 hours. The rate of decomposition was influenced by temperature and aeration of the water. A 16° C increase in temperature resulted in a four-fold reduction of phenolic activity. Aerated solutions showed a two-fold reduction in phenolic activity compared to nonaerated solutions. Passage of the leachate through soil cores resulted in approximately 50% reduction in phenolic activity due to decomposition and attachment of the phenolics to soil particles.

Bioassays using stonefly and mayfly nymphs subjected to concentrations as high as 80 mg/l of phenolic activity resulted in a maximum of only 20% mortality. Rainbow trout were tested at three ages, ranging from 3 days to 8 weeks after hatching. The maximum concentration that could be expected under natural conditions was estimated to be less than 40 mg/l of phenolic activity.

Results of this study indicate that, in general, organic compounds leached from wood chips, bark, and needles will not adversely affect water quality.

Research Agreement 16-297-CA
Colorado State University
H. Leo Teller, Principal Investigator

Desmore, Gabriel A. II-7
1978. Changes in water quality and fish fauna in the Rio Grande between Elephant Butte Dam and Caballo Lake. 33 p. plus 4 figures and 11 tables.

The Rio Grande River between Elephant Butte Dam and Caballo Lake in southern New Mexico is being used for irrigation water and municipal waste disposal from the communities of Truth or Consequences and Williamsburg. Moreover, Cuchillo Negro Creek, Mescal Canyon, Palomas Creek, and the collective flows of hot mineral springs in the Truth or Consequences area are sources of naturally occurring physical and chemical additions to the Rio Grande.

Because irrigation water is also used for hydroelectric power generation, water is released from Elephant Butte Reservoir to coincide with peak power demand. This has resulted in considerable changes in flow rates and river water levels.

Tests showed changes in the water quality of the river and in the biological community. Water quality changes were the result of human activity and natural phenomena. The faunal changes were not totally a result of the water

quality changes, but were also directly influenced by the varying physical characteristics of the river channel resulting from human activity and natural phenomena.

Research Agreement 16-694-GR
New Mexico State University
Douglas B. Jester, Principal Investigator

Doehring, Donald O., and Frank G. Ethridge. II-8
1977. Estimating coarse sediment in mountain watersheds. 44 p. with 8 figures and 3 appendices.

This study was conducted on the South Fork of the Cache La Poudre River in Colorado. The results were as follows:

Objective A.--Develop a procedure for predicting sediment discharge given hydrologic, morphologic, and sedimentologic inputs. This goal was successfully met within the range of data that could be collected. The predictive model is in the form of a power function. The regression equation explains over 96% of the variance in the data and has a standard error of the estimate of 0.35.

Objective B.--Estimate the median bedload size moved by floods of various return periods. The invalidity of extrapolation from flood frequency equations precludes meeting this goal as the greatest discharges available for the collection and measurement of data were below 2.33 year event.

Objective C.--Develop the capability to estimate bedload movement for a given grain size under given hydrologic conditions. It was found that stream power (w), unit tractive force (t_o) (also known as unit shear stress), and water discharge (Q_w) were useful. Folk statistics (graphical statistics of cumulative grain size distributions) were used to measure grain size.

Objective D.--Test the applicablity of David Rosgen's (USDA Forest Service) channel stability techniques for estimating sediment yield. The results of our work are consonant with the underlying concepts and methodology developed by Rosgen, but this method does appear to be valid within the limited range of data we were able to collect.

Unusually good access to and exposure of the stream channel as a result of low stream flow, along with high quality hydrologic and sediment measurements, have been used to devise a new technique for estimating hydraulic roughness, an especially difficult problem in steep mountain streams. The basis for the new improvement is the measurement of channel armor fabric; a combination of particle size, shape, and orientation.

Research Agreement 16-584-GR
Colorado State University
Donald O. Doehring, Principal Investigator

Garcia, John D., Brian Gontarek, and Mark Rhodes. II-9
1978. A survey of the levels of 2,4,5-T and TCDD in soils from treated areas within the White River watershed, and in mud and water from White River Reservoir, Crosby County, Texas. 36 p.

Analysis of soils, lake sediments, organic matter, and water for residues of 2,4,5-T and TCDD by electron capture chromatographic techniques indicate a low persistence of 2,4,5-T, little vertical leaching in soils, and only a slight transport into an aquatic system. No verifiable residues of TCDD were detected in any of the samples. Residues of 2,4,5-T in soils from treated areas averaged 19.26 parts per billion by weight (ppbw) in samples at a depth of 0 to 15.0 cm, 1 to 3 days after aerial application of 0.56 kg/ha isooctyl ester. Concentrations decreased to 9.40 ppbw by July 20, 1976, 3.19 ppbw on December 27, 1976, and less than 1.0 ppbw on July 20, 1977. Mean residue levels at depths greater than 15.0 cm never reached 2.0 ppbw during the period of this study and were generally less than 1.0 ppbw or not detectable. Sediments from at least one of six in-lake stations contained concentrations between 1.0 and 2.0 ppbw from July through October 1976. After October 1976, sediment residue concentrations were less than 1.0 ppbw or below detectable levels. Organic matter samples strained from lake sediments at station 2 contained 1.70 ppbw on June 30, 1976, reached 2.27 ppbw or to nondetectable levels during the reminder of this study. Water samples collected at six in-lake stations yielded mean values less than 0.5 ppbw throughout this study. Other data gathered on physiochemical characteristics of the lake indicate concentrations of 2,4,5-T in sediments, organic matter, or water were closely associated with several variables.

Research Agreement 16-591-GR
Texas Tech University
John D. Garcia, Principal Investigator

Gosz, James R. II-10
1975. The effects of road salting on the functioning of a forest ecosystem. 16 p. plus 18 tables and 7 figures.

A study was conducted on the Tesuque watershed on the Santa Fe National Forest along the access route to the Sante Fe Ski Basin. The purpose was to determine the amounts of Na and Cl ions held or lost from forest ecosystems subject to road salting and determine the interactions between the Na and Cl and the other nutrients in the system.

It was found that (1) the substances studied enter streams in significant quantities, but did not reach levels harmful to aquatic life; (2) the substances caused losses in Ca, Mg,

and K, and gains in Na in the nutrient budgets; and (3) the substances significantly altered the nutrient cycling characteristics of the system with resulting damage to the vegetation.

The sand and salt mixtures used on snow-covered highways caused significant damage to adjacent vegetation. However, a reduction in the amount or proportion of salt used may not reduce the damage. The sand also resulted in significant change in soil texture so changes in the mixture only enhances sand damage. It was suggested mass transportation alternatives that would reduce the dependency on salt and sand be examined.

Research Agreement 16-451-CA
University of New Mexico
James R. Gosz, Principal Investigator

Gosz, James R. II-11
1975. Quantitative evaluation of disturbances associated with ski area development. 34 p.

The report evaluates the changes in water quality of adjacent streams due to the development of additional capacity on a ski area in New Mexico. It describes the vegetative changes that the lift construction caused and provides data on hydrology and stream chemistry. It was found that clearing of the ski runs and construction of ski lifts caused an increase in stream discharge but did not significantly affect stream chemistry.

Research Agreement 16-443-CA
University of New Mexico
James R. Gosz, Principal Investigator

Gosz, James R. II-12
1975. Stream chemistry as a tool in evaluating ski area development.

Studies were made on a series of ski area developments representing increasing impact severity to a single area as well as different areas subject to different types of impacts. The major factor affecting water quality was road salt application. Sewage disposal affected inorganic water quality to a minor degree, while poma-lift construction and light tree removal had no measurable effect on the water quality parameters measured. Site productivity appeared to be more affected than water quality.

Research Agreement 16-293-CA
University of New Mexico
James R. Gosz, Principal Investigator

Published in Eisenhower Consortium Bulletin 1, p. 183-194.

Gosz, James R. II-13
1977. Effects of ski area use on biological and heavy metal aspects of water quality. 22 p. plus 24 tables and 6 figures.

This study was undertaken to determine if there is presently any degradation of water quality resulting from activities at the Santa Fe Ski Basin in New Mexico. The research focused on the heavy metal aspect of chemical water quality and the sanitary health aspect of biological water quality.

The Santa Fe Ski Basin did not contribute significantly to the total bacterial counts in samples taken below the ski area, and heavy metal concentrations were significant only near parking areas and along roads. Also, particulate matter and heavy metal content of stream water were, as would be expected, higher below the ski area than above, and road salt concentrations were significant along roads leading into the Basin.

It was suggested that better revegetation of disturbed areas could reduce losses of particulate matter and transport of heavy metals out of the Basin.

Research Agreement 16-520-CA
University of New Mexico
James R. Gosz, Principal Investigator

Published as Eisenhower Consortium Journal Series Paper 13: Effects of ski area development and use on stream water quality of the Santa Fe Basin, New Mexico. Forest Science 23(2):167-179, 1977.

Gosz, James R., and Manuel C. Molles. II-14
1977. Longitudinal recovery of a stream affected by a ski area development. 20 p. plus 5 tables and 19 figures.

Past studies of the Rio en Medio have demonstrated significant alterations of water quality and communities of invertebrates below the Santa Fe Ski Area. The present study was undertaken to determine how far downstream the effects of the ski area extend.

The concentration of every major nutrient except sulfate ion was found to increase below the ski area, and the only mechanism for recovery seemed to be dilution by downstream tributaries. Sediment loads also increased below the ski area. Peaks of sediment transport were associated with snowmelt and summer rains. Much of the increased sediment below the ski area appeared to settle out in the upper reaches of the Rio en Medio.

Although composition and diversity of stream insects appeared to be little affected, numbers and biomass were significantly reduced below the ski area. These reductions were attributed to the effects of increased sediment load. Some recovery of invertebrate production was recorded 500 and 2,000 m below the most heavily impacted site.

Research Agreement 16-698-GR
University of New Mexico
James R. Gosz, Principal Investigator

Grant, Michael C., and II-15
William M. Lewis.
1976. Nutrient movement in a mountain watershed supporting light residential development. 10 p. plus 25 figures and 1 table.

The study is one of a series and was conducted in 1975 to develop baseline data and compare nutrient movement in pristine and developed watersheds. Samples and measurements were taken from different sections at Como Creek, Colorado Watershed, and analyzed at the University of Colorado's Alpine Research Station. The data indicate light residential development greatly increases stream levels of alkalinity, orthophosphate, nitrate, calcium, magnesium, sodium and potassium; slightly increases pH levels; decreases stream levels of total dissolved organics, dissolved organic nitrogen, and sulfates; and has little effect on stream levels of dissolved organic phosphorus, nitrates, and ammonia.

Research Agreement 16-529-CA
University of Colorado
Michael C. Grant, Principal Investigator

Grant, Michael C., and II-16
William M. Lewis.
1977. Nutrient improvement in a mountain watershed supporting light residential development. 26 p. plus appendices.

Substantial differences exist in the chemistry of Como Creek, Colorado, water above and below the zone of human influence. Alteration of the watershed has increased the export rate of calcium, magnesium, sodium, potassium, bicarbonate, nitrate, phosphate, and dissolved organic phosphorus. The amount of dissolved organic carbon in the stream is significantly lowered as the stream passes through the altered portion of the watershed. The principal changes caused by human activity appear to involve principally the dissolved components of stream water, as the composition of particulate material from stream water taken at the two sampling stations is essentially identical.

Human use of the watershed exaggerates the seasonal fluctuation in certain inorganic substances, and also alters the periodicity in concentrations of certain dissolved organic materials.

The input rate for all substances, including both soluble and insoluble materials, is substantially greater for bulk precipitation than for dry fallout. The alkalinity of dry fallout samples is greater on a unit area basis than bulk precipitation samples, but this is accounted for by the greater amounts of mineral acids present in bulk precipitation than in dry fallout. The ratios of inputs between dry fallout and bulk precipitation differ radically between ionic types.

The inputs to the Como Creek Watershed do not appear to differ significantly between sampling stations. Many chemical components show a pronounced seasonal periodicity. Maximum input of many components occurs during spring and early summer.

Research Agreement 16-582-CA
University of Colorado
Michael C. Grant, Principal Investigator

Grant, Michael C., and II-17
William M. Lewis, Jr.
1978. Nutrient movement in a mountain watershed supporting light residential development. 31 p. and 2 appendices containing tables and charts.

This study, the third in a series, was undertaken to develop baseline data on nutrient movement and to compare nutrient flux in pristine and developed sections of a watershed. It was found that (1) there are substantial differences in water chemistry of a stream above and below human development, (2) human use exaggerates seasonal fluctuations in concentrations of organic substances in stream water, and (3) input rates of all substances except particulates and bicarbonate are greater for bulk precipitation than for dry fallout alone.

Research Agreement 16-697-GR
University of Colorado
Michael C. Grant, Principal Investigator

Hasfurther, Victor R., and II-18
Timothy R. Conner.
1977. Development of criteria to control sediment discharges from recreation-related forest roads near streams. 56 p. illustrated.

This study was undertaken to analyze the use of various natural systems or existing materials to limit the entry of sediments into streams from forest roads. The major factors that contributed to a method for entrapment of sediment were the road gradient, buffer zone slope, road age, number of obstructions, and type of obstruction. These variables were used to estimate the volume of sediment flow. Other factors which were found to have some effect on sediment volume and flow, but were not used in the method developed, were drainage area, road area, and runoff volume. The different types of obstructions, listed in descending order of ability to retain sediment, are mounds and depressions, fallen timber, brush and shrubs, live trees and stumps, rocks and rock barriers, and low-lying vegetation. Fallen logs appear to be the most economical to trap sediment

in most circumstances because of availability and ease of placement. Mounds and depressions should be considered whenever logs are not available.

A method was developed for determining the number of obstructions and spacing to prevent road sediments from reaching a natural stream. It should be applicable to watersheds and roads located on granitic soils with similar climatic conditions.

Research Agreement 16-515-CA
University of Wyoming
Victor R. Hasfurther, Principal Investigator

Hasfurther, V. R., and D. H. Foster. II-19
1978. Control of sediment discharges and water quality below recreation-related roads. 41 p.

Criteria and construction practices that affect sediment movement from road construction in forested areas of the Medicine Bow National Forest were evaluated. Snowmelt runoff has, in general, a lesser effect on sediment transport than intense summer thunderstorms.

Twenty sediment control devices of four different classes have been established on two study areas in the Medicine Bow National Forest. Natural vegetation and low-lying shrubbery areas are the most cost efficient, but are unsuitable in most areas because the amount of vegetation is insignificant and slope gradients too large. Log structures were found to be the most cost efficient and sediment-productive of all devices. Catch basins consumed more man-hours than log structures, and gabions required both extra expense for material and more man-hours than either log structures or catch basins. Material availability will be the most critical determining factor under most construction situations. However, where logs are available, log structures will be the most reasonable device to install from both cost and sediment-trapping considera tions.

Research Agreement 16-587-GR
University of Wyoming
Victor R. Hasfurther, Principal Investigator

Johnson, Roy M. II-20
1975. Development of a practicable system for monitoring the microbiological characteristics of forest lakes. 45 p.

Bacterial counts were made in two artificial forest lakes in Arizona; one receiving heavy recreational use and one receiving only light use. The lake receiving the heaviest use had the highest levels of fecal indicator bacteria; the highest levels of contamination occurred along the shores of both lakes. Also, while fecal indicator bacteria occur in lakes as a result of human use, they do not appear to survive there in significant numbers.

The research revealed that the presence of Chromobacter lividum and Cytophaga johnsoni can be used as indicative of good quality and their absence as suggestive of pollution. Testing for these two species of bacteria could be used as a rapid screening method of determining water quality.

Research Agreement 16-444-CA
Arizona State University
Roy M. Johnson, Principal Investigator

Molles, Manuel C. II-21
1978. Effects of road salting on aquatic invertebrate communities. 29 p. including. 7 tables and 5 figures.

The application of salt and sand to roads in winter recreation areas increases concentrations of salts and sediments in nearby streams. This study was undertaken to determine the effects of these concentrations on stream invertebrates, particularly those important as trout forage. It was found that:

1. Reaches of streams receiving drainage from salted roads were shown to support reduced biomass and numbers of stream invertebrates during certain seasons.
2. Salting and sanding did not appear to affect the composition and diversity of insects of the orders Ephemeroptera, Plecoptera, Trichoptera, and Coleoptera.
3. The effects of road salting on invertebrate communities was most likely the result of increased input of fine sediments into below-road reaches of the study streams.
4. Major reductions in biomass and numbers of invertebrates caused by road salting could be expected to lower production of trout.
5. Production of oligochaete worms seemed to be favored in the most severely impacted streams. A shift to production of oligochaetes over other invertebrates, especially stream insects, would probably lead to reduced production of trout even if total biomass were not affected.

It is recommended that the inputs of fine sediments from salted roads be reduced by roadside revegetation with salt-tolerant species.

Research Agreement 16-589-GR
University of New Mexico
Manuel C. Molles, Principal Investigator

Parker, M., R. G. Elder, and F. E. Payne. II-22
1977. Predicting aspects of water quality from phosphorus mass budget models and algal bioassays. 78 p. with 23 figures, 2 tables, and 5 appendices.

The study found that Dillon's (1975) phosphorus mass budget model did not accurately predict phophorus concentrations in four Wyoming

lakes because flushing rates in the lakes were very large. Thus, predictions as to the effect of increased phosphorus loading on algal growth are dependent on flushing rates. When the flushing rate equals or exceeds algal reproductive rates, the relationships between phosphorus concentrations or loading and water quality parameters are invalid.

Research Agreement 16-586-GR
University of Wyoming
Michael Parker, Principal Investigator

Ponce, S. L., and J. Dederick. II-23
1969. Impact of second home developments on water quality in areas of low precipitation. 94 p. including appendices.

Results indicated only minor degradation of surface water quality on a weekly basis. Suspended solids and primary nutrient concentrations were similar at both the upstream and downstream sites at each of four study areas. Indicator bacteria densities varied slightly more than the other parameters, but were still relatively consistent between sites. Fecal coliform to fecal streptococci ratios (FC/FS) were less than 0.7 in almost all instances, suggesting that livestock and wildlife had a larger influence on the water quality than the developments.

Appreciable increases in suspended solids and indicator bacteria were evident during stormflow. However, these increases were proportional at both the upstream and downstream sites at each study area. The increases in suspended solids concentrations appear to be channel derived. No adverse effects from the road systems at these developments were observed during storm sampling. Bacteriological ratios were all less than 0.7 which suggests that the source of fecal contamination was not human.

In general, the developments studied do not appear to be affecting the water quality of the nearby streams regardless of housing density or type of sewage facilities utilized.

Research Agreement 16-659-GR
Colorado State University
Stanley L. Ponce, Principal Investigator

Segall, Burton A. II-24
1973. The effects of second homes and related vacation developments on the quality of Arizona streams and groundwater: Pinewood. 28 p.

Wastes discharged by rapidly developing, privately owned recreational communities constitute a threat to forest environments. A study conducted in the Pinewood vacation subdivision south of Flagstaff, Ariz., found that Pinewood sewage had contaminant levels similar to ordinary residential communities, but the sewage treatment plant at Pinewood was easily upset because of the wide seasonal variation in sewage flow. Thus, water contamination is a very real possibility. The study recommends the adoption of septic-tank disposal systems, where possible, and the retention of waste water within the community boundaries through water reuse or soil disposal where other systems are used.

Research Agreement 16-298-CA
Arizona State University
Burton A. Segall, Principal Investigator

Published as Eisenhower Consortium Bulletin 3, 19 p. 1976. The impact of vacation homes on national forest water resources.

Segall, Burton A. II-25
1974. The effects of second homes and related vacation developments on the quality of Arizona streams and groundwater: Oak Creek Canyon. 49 p.

The public and private lands in Oak Creek Canyon have public day use and overnight campsites served by vaulted privies, and private second-home and trailer park developments served by individual septic tanks. Bacterial counts in Oak Creek were not excessively high, especially near campground and second home developments. The highest counts were obtained adjacent to trailer park developments. The present systems of sewage disposal are adequate, and central sewer system with secondary treatment facilities is not recommended.

Research Agreement 16-335-CA
Arizona State University
Burton A. Segall, Principal Investigator

Published as Eisenhower Consortium Bulletin 3, 19 p. 1976. The impact of vacation homes on national forest water resources.

Segall, Burton A., and II-26
George E. Hoag.
1977. Improved methods for the treatment and disposal of second home waste waters. 76 p. with 15 tables and 25 figures.

Analyses of physical, chemical, and biological processes in conventional septic tanks showed that practices in the home have an important effect upon septic tank functioning, with the length of time between tank pumping being the key parameter.

Septic tanks have three distinct layers: (1) the scum layer, which consists of floatable organic solids such as fats, grease, and oil, and soluble inorganic and organic materials as phosphorus and volatile acids; (2) the supernatant layer, which consists of discharged sewage from the home and is the liquid that is discharged from the tank to the leaching field; and (3) the sludge layer, which is the result of

solid deposition in the tank. Treatment occurring in the sludge layer involves some conversion of organics to volatile acids which may either be washed from the tank or float to the surface.

Anaerobic digestion can be improved by limiting the introduction of oxygen by supernatant mixing with sludge layers and by increasing the temperature of tanks. The latter is possible through low-energy solar heating. The requirements and potential use of solar heating are discussed.

The development of anaerobic treatment of septage will consist of a central completely mixed heating anaerobic digester for primary treatment containing various concentrations of septage and domestic sewage. A settling tank followed by an anaerobic filter should be a suitable secondary treatment system.

Rotating biological discs have great potential for the treatment of high strength organic wastes such as septage.

Research Agreement 16-593-GR
Arizona State University
Burton A. Segall, Principal Investigator

Segall, Burton A., and Stewart M. Oakley. II-27
1975. Development of a system for monitoring the physical and chemical characteristic of forest lakes. 77 p.

Studies were conducted on two forest lakes in Arizona--one heavily used by recreationists and one lightly used--to evaluate differences in water quality resulting from recreational uses and develop indices for detecting water quality changes. It was found that the best indices for describing the immediate effects of environmental changes are dissolved oxygen profiles, turbidity, total dissolved solids, and organic content of sediments. Moreover, changes in lake productivity are best indicated by diurnal dissolved oxygen fluctuations, total water hardness, alkalinity, and total phosphorus content.

It was concluded, based on the use of the above indicators, that recreational activities were having negligible effect on water quality in both the study lakes.

Research Agreement 16-445-CA
Arizona State University
Burton A. Segall, Principal Investigator

Skinner, Quentin D., and John C. Adams. II-28
1976. Water quality near a ski area on the Medicine Bow National Forest. 79 p.

Water samples were collected above and below a ski area in Wyoming from October 1975 through May 1976, and analyzed at the Chemical and Bacteriological Laboratory in Laramie. The data indicate there were no significant differences during the fall months. Significant increases in bacterial counts did not appear until February, and they began to decline in May to the levels obtained in the previous October. The rise in bacterial counts in February through April was probably due to the filling of the holding pond during these months with increased ski area usage. Moreover, there may be a time lag in count increases due to the slow movement of waste water through the soil during the winter months. Daily data indicate a definite time lag between heavy restroom use and increased bacterial counts in the stream.

Research Agreement 16-516-CA
University of Wyoming
Quentin D. Skinner, Principal Investigator

Wemple, Robert E. II-29
1978. Nutrient removal from wastewater treatment facilities in mountainous resort communities. 191 p. with 32 tables and 21 figures (M.S. thesis).

For activated sludge facilities, conversion of ammonia to other forms of nitrogen by biological nitrification is the preferred method of removal.

Phosphorus removal in activated sludge facilities involved chemical addition followed by clarification and/or filtration. Lime is commonly used; however, sludge handling problems may lead to the selection of more expensive but better chemicals such as aluminum or iron salts. Alum probably provides the lowest effluent phosphorus concentrations under most conditions. Both tertiary clarification and final filtration were efficient solids removal processes for phosphorus removals.

Lagoon systems and small extended aeration plants are not easily adaptable to provide nutrient removal. The nitrification process is more easily controlled with extended aeration plants than are lagoon systems.

Research Agreement 16-657-GR
University of Colorado
J. Ernest Flack, Principal Investigator

Windell, John T. II-30
1978. The on-stream effects of an off-stream reservoir. 39 p. with 15 tables.

The purpose of this study was to assess the effects of a tributary reservoir system (i.e., an off-stream system, Williams Fork) on a mainstream river system (i.e., on-stream, Colorado River). Physical habitat, water flow, water quality, macro-invertebrate benthos, and fish populations were compared. Since construction of the dam-reservoir system, mean annual water flow (ft^3/s) has been reduced by 54% in the off-stream Williams Fork River and by 63% in the

main-stream Colorado River. Decreased water flows in both streams caused a 10% (22.5% to 33.4%) increase in dilution of the Colorado River by the Williams Fork River. A more than 50% decrease in water flow caused a similar decrease in wetted streambed area, mean water depth, and loss in recreational area and value. Standard water quality analysis indicated no significant positive or negative effects of the offstream tailwater on the mainstream Colorado River. However, an altered tailwater temperature regime significantly altered species composition, lowered species diversity, lowered species equitability, and decreased in the main-stream Colorado River. Short-term tailwater flow fluctuations (ranging from 0 to 250 ft^2/s) combined with abnormal water temperatures appeared to eliminate salmonid fishes. Severe reservoir drawdown resulted in periodic heavy siltation and a persistent high turbidity in the off-stream tailwater and below the Williams Fork--Colorado River confluence, which may have prevented spawning of salmonids in the spring and fall.

Research Agreement 16-583-GR
University of Colorado
John T. Windell, Principal Investigator

Ziebell, Charles D., and Carla J. Fisher. II-31
1978. The influence of watershed uses on water quality and the subsequent effect on fisheries in mountain lakes. 30 p. with tables, figures, and appendices.

This study was undertaken to determine the sources of nutrients leading to eutrophication of lakes, and to determine the effects of various levels of eutrophication on trout habitat conditions. Four lakes in Arizona were studied, and it was found that three had heavy algal blooms and high levels of eutrophication. Concentrations of nitrogen and phosphate were similar in all four lakes.

It was determined that most of the nutrients that caused eutrophication came from heavy cattle use on the watershed before impoundment and leaching from the fertile soils of the watershed. Campgrounds, grazing, trailer parks, and oxidation ponds near one of the lakes did not appear to add to the lake nutrient content to an appreciable extent.

A high level of nutrients in the lakes was harmful to trout. Lake stratification during the summer forced trout to stay in the upper 1.5 to 2 m of water where sufficient dissolved oxygen was available. However, the water had high pH values, water temperatures, and un-ionized ammonia concentrations which caused mortalities ranging from 20% to 100%.

Research Agreement 16-595-GR
University of Arizona
Charles D. Ziebell, Principal Investigator

Additional information on water quality may be found in the following abstracts: V-9, VI-7, and VII-15.

III. Watershed Management

Bedunah, Donald, and M. J. Trlica. III-1
1977. Highway salting influences on ponderosa pine seedlings. 100 p. (M.S. thesis).

Results of winter lath house irrigations and foliar sprays with sodium chloride solutions (3,000, 6,000, and 9,000 p/m) suggest direct ion toxicity. There is also evidence that net photosynthesis could be decreased without a subsequent increase in foliar injury.

Research Agreement 16-531-CA
Colorado State University
M. J. Trlica, Principal Investigator

Bohren, Craig F. III-2
1975. Modification of snowpack physical properties and dynamics by snowmobile compaction. 2 p.

The purpose of this study was to determine if snowmobile compaction can result in different ablation rates in snowpack. Test sites were established on the Fort Valley Experimental Forest and the Coconino National Forest and instrumented to measure temperature and heat flux in the soil and water equivalent, albedo, density, and grain size in the snowpack.

No experimental data were obtained as the study sites received little snow, and the winter weather pattern consisted of short periods of storms followed by long periods of warm weather which caused rapid melting. No analyses could be made and no conclusions could be drawn.

Research Agreement 16-450-CA
University of Arizona
Craig F. Bohren, Principal Investigator

Bohren, Craig F., and Bruce R. Barkstrom. III-3
1974. Theory of optical properties of snow. 43 p.

The optical properties of a snowpack are calculated, giving relations between the asymptotic flux extinction coefficient and albedo under diffuse illumination on the one hand, and the density, grain size, and wavelength on the other. A geometrical optics calculation of the properties of a single grain is used with approximate solutions of the radiative transfer problem. Most of the scattering is the result of change in direction of the light beam upon transmission through grain, rather than reflection. The asymptotic flux extinction coefficient is directly proportional to snowpack density and inversely proportional to the square root of the grain size. The albedo under diffuse illumination is independent of density and proportional to the square root of the grain size. The derived relations agree with experimental data within 20% for the flux extinction coefficient and to better than 2% for the albedo, using no adjustable parameters. Higher values of the flux extinction coefficient will be measured if the snow is confined within a finite cylinder with absorbing sides. An analysis of the effect is given.

Research Agreement 16-295-CA
University of Arizona
Craig F. Bohren, Principal Investigator

Published as Eisenhower Consortium Journal Series Paper 4, in Journal of Geophysical Research 79(30):4,527-4,535.

Carroll, T., and N. Caine. III-4
1974. Volume and role of stream discharge from an alpine snowpack. 22 p. plus tables, figures, and appendices.

A study was made of snow accumulation and water yield from a stream basin above timberline in the Colorado Front Range. Precipitation, ablation, and stream discharge data were used along with estimates of evapotranspiration to construct a water budget. No elements of the water budget were figured by subtraction; consequently, an error term is given in centimeters of water equivalent. Total generated discharge for the entire basin is 59.64 cm while the error is -9.78 cm or -16.4%. The cause for the relatively large underestimate of the water budget is undoubtedly associated with the difficulties in determining the generated discharge at one test site.

Research Agreement 16-292-CA
University of Colorado
N. Caine, Principal Investigator

Gosz, James R. III-5
1974. Effects of road surfacing and salting on roadside vegetation in New Mexico mountain areas. 32 p.

The increased winter use of forested areas for recreation has resulted in increased road improvements and road salting. The effects of these activities on roadside vegetation were examined and evaluated. It was found that trees within 8 m of a road are stressed when roads are improved and salted. Damage appears first in August with the greatest amount being found in September. However, total damage and rate of development varied widely between sample plots.

The major factors related to the occurrence of damage were road shoulder width, which seems to control water flow to roadside vegetation; slope, which is related to drainage; and sand content of the salt/sand mixture, which changes the soil texture over time.

The report contains detailed tables and a number of recommendations.

Research Agreement 16-361-CA
University of New Mexico
James R. Gosz, Principal Investigator

Gosz, James R. III-6
1977. Effects of soil amendments on vegetation stressed by road salt. 11 p. plus 6 tables.

Increased use of forested areas for winter recreation activities has resulted in increased winter road salting. Past research identified many factors which contribute to vegetation damage, so this study was undertaken to determine if applications of straw mulch and humate (a carbonaceous claystone) would control or reduce undesirable effects of road salting.

The research indicates that it is very difficult and expensive to completely stop salt damage to the natural vegetation. Soil additives can reduce the damage by increasing soil-moisture-holding capacity. However, very heavy applications will be required as stress on New Mexico forest species caused by modest salt levels causes reductions in productivity and resistance to disease and insect attack. It seems that establishment of salt-tolerant and cool-tolerant grasses may be the best management practice to reduce salt damage.

Research Agreement 16-524-CA
University of New Mexico
James R. Gosz, Principal Investigator

Graybeal, Nancy. III-7
1973. An analysis of vegetation on ski slopes at the Winter Park ski area. 108 p. (M.S. thesis).

Erosion on ski areas could become a problem unless vegetative cover is retained. Sixteen ski slopes in Colorado were studied to determine the type and amount of vegetation present and to evaluate the effects of elevation and age on the cover.

It was found that 92% of the 84 species found were intolerant perennials with genus Vaccinium being the most important. Non-native Trifolium, Poa, and Phleum were also very important.

There was a significant increase in total vegetation cover of forbs, sedges, and rushes, and in the number of species, as the ski slopes increased in age. Elevation had little effect on vegetative cover.

Live vegetation is not necessary for soil stabilization. Large amounts of dead organic material prevent erosion as well as living cover.

Research Agreement 16-294-CA
Colorado State University
Gilbert H. Fechner, Principal Investigator

Hughes, William C. III-8
1978. Channel erosion risk index. 64 p. with tables, figures, and four appendices.

This study developed a test procedure to aid land use planners and developers in appraising potential for erosion on given sites. The erosion potential (erosion risk) is expressed as an index. The probability of significant erosion in any given year or recurrent intervals can be used to evaluate the likelihood that recreation-related developments or roads along a stream might significantly increase channel erosion. It was found that:

1. With possible exception of precise location of interior erosion potentials, the channel erosion risk procedure provides a sound way to estimate the risk of severe erosion in stream channel.
2. The procedure described does provide a quick method to estimate the erosion risk in a stream channel using easily obtained data.
3. The sand-silt, silt-clay, and clay erosion potentials are statistically reliable to an acceptable degree, but estimates of the gravel-silt erosion potential are only marginal.
4. The erosion risk index computed with the normal depth-normal velocity erosion potential diagrams is highly sensitive to small variations in the Manning roughness coefficient.
5. The channel erosion risk indexes developed are valid only for bare soil conditions. A possible means for incorporating the effects of a grass cover would be to reduce the velocity linearly from the permissible velocity of bare soil to the permissible velocity with appropriate grass cover.

Research Agreement 16-658-GR
University of Colorado
William C. Hughes, Principal Investigator

Mason, Mark L. III-9
1976. The effects of commercial clearcut harvesting on the nutrient status of soil. 39 p. (M.S. thesis).

Nineteen years after harvest, soil samples were collected from the site and analyzed for nutrient concentrations. Statistical analysis revealed that clearcutting of trees caused no significant reduction in the concentration of nutrients in the mineral soil. In fact, concentrations of soluble calcium and magnesium, and extractable calcium, magnesium, and potassium, were found to be higher in soil from the harvested areas.

Supplemental reports:

1. Role of mineral soil in supplying nutrients to regenerating lodgepole pine seedlings. 28 p. plus appendix (mimeo). A regenerating stand of lodgepole pine seedlings contained 7

times more calcium and magnesium, 2.5 times more potassium, and 107 times more phosphorus than was available for uptake in the mineral soil. Thinning returns nutrients to the leave trees, but increases the rate of fire spread.

2. Effect of clearcutting on snowpack profile and wood production of adjacent stands. 13 p. plus appendix (mimeo). Statistical analyses of field data did not indicate either beneficial or adverse effects of changes in snowpack profile due to clearcutting on wood production in adjacent stands.

Research Agreement 16-459-CA
University of Wyoming
Paul C. Singleton, Principal Investigator

Nations, J. Dale, and III-10
Raymond L. Eastwood.
1975. Potential environmental impact of future surface mining operations on the Coconino National Forest. 50 p. plus maps.

The report indicates those areas on the Coconino where surface mining operations could occur profitably and efficiently and outlines the potential environmental impacts of future mining in terms of the visual or esthetic effects. The appropriate use of rock materials and areas of potential ground water production are suggested.

Research Agreement 16-346-CA
Northern Arizona University
J. Dale Nations, Principal Investigator

Reid, C.P.P. III-11
1975. Control of the mountain pine bark beetle by Paraquat. 10 p.

In ponderosa pine treated with Paraquat, the amount of induced resin soaking was small compared to that observed in the southern pines, and no qualitative changes in oleoresin composition were induced. However, the Paraquat treatment inhibited blue stain infections above treatment frills as well as pure culture growth of the fungal symbionts of the mountain pine beetle. There was no statistical evidence that Paraquat treatment of ponderosa pine will either increase the propensity to attack or reduce or prevent attack by the mountain pine beetle.

Research Agreement 16-467-CA
Colorado State University
C.P.P. Reid, Principal Investigator

Additional information on Watershed Protection may be found in the following abstracts: II-11, VI-8, VI-11, VI-12, VI-19, VII-3, VII-13.

IV. Wildlife

Bailey, James A., and Gregory R. Rost. IV-1
1976. Responses of deer and elk to roads on the Roosevelt National Forest. 19 p.

Measurement of fecal pellet-group density and visual estimation of seven habitat variables along transects perpendicular to forest roads provided a broadly applicable method for evaluating ungulate response to roads. Multiple regression analysis permitted evaluation of ungulate responses to roads independent of influences of other variables that are often correlated with distance from roads. In the mountain shrub and ponderosa pine vegetation zones on the Roosevelt National Forest, Colorado, deer and elk pellet-group densities increased with distance from roads. Deer avoidance of roads was greater in the mountain shrub zone than in the ponderosa pine zone. Paved, gravel, and unimproved dirt roads were avoided. Limited data for elk indicated that elk avoid gravel roads but not dirt roads, which are usually snowbound when elk are present, in the ponderosa pine zone. It is not known if deer or elk will avoid roads to an extent that is detrimental to their welfare.

Research Agreement 16-392-CA
Colorado State University
James A. Bailey, Principal Investigator

Davis, Peter R. IV-2
1976. Response of vertebrate fauna to forest fire and clearcutting in south central Wyoming. 94 p. (Ph.D. dissertation).

An investigation in the Medicine Bow and Sierra Madre Mountains of southcentral Wyoming compared selected burns and clearcuts of the same age with each other and with forested controls and with natural openings. Differences in the effects of logging and fire on populations of mule deer, elk, small mammals, and birds were determined, and the reasons for the differences were evaluated. Recommendations were made so that clearcutting would more closely simulate forest fire.

Clearcuts supported more small mammals than burns, and numbers of total small mammals were correlated with the amount of cover present. It was recommended that some logging residue be left to supply escape cover for small mammals.

Fecal-group counts indicated 49% of deer use and 51% of elk use was in burned areas, while 26% and 13% other use occurred in clearcut plots. The remainder of animal use was in natural openings and forested plots. Deer and elk preferred areas with standing dead timber which acted as escape cover.

In all plots the majority of birds were ground feeders and branch nesters. Bird species richness was related to plant species richness and the amount of standing dead timber present. Standing dead timber is necessary to supply nesting habitat and is possibly a limiting factor when scarce.

A wide variety of plant species present in burned plots provided food for a wide variety of insect species, which in turn provided food for a wide variety of bird species. Both fire and clearcutting provide ample foraging opportunities for ground-feedings birds.

Research Agreements 16-391-CA and 16-464-CA
University of Wyoming
Peter R. Davis, Principal Investigator

Published as Eisenhower Consortium Journal Series Paper 14, Davis, Peter R. 1977. Cervid response to forest fire and clearcutting in southeastern Wyoming. Journal of Wildlife Management 41(4):785-788.

Franzreb, Kathleen E. IV-3
1976. Bird population changes after timber harvesting in a mixed conifer forest in Arizona. 69 p. with 5 tables.

Selective overstory removal in a mixed conifer forest in the White Mountains of Arizona significantly lowered total bird density. However, a number of species attained higher densities in the logged area than in the control area. In both habitats, avian usage of Douglas-fir, white fir, and Engelmann spruce far exceeded that expected on the basis of foliage volume. Birds were more frequently observed on snags and in quaking aspen in the logged areas than in the control site. Gray-headed juncos utilized logging slash heavily. Tall trees were preferred in both habitats. The behavior of yellow-bellied sapsuckers, mountain chickadees, ruby-crowned kinglets, yellow-rumped warblers, and gray-headed juncos was examined with regard to tree species selection and tree height preferences. Timber harvesting affected the behavior of some species, but for others there was little change.

Research Agreement 16-296-CA
Arizona State University
Robert D. Ohmart, Principal Investigator

Published as USDA Forest Service Research Paper RM-184, 26 p. 1977. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Garcia, John D., and Brian Gontarek. IV-4
1978. The effects of repeated low level exposure of selected fish species to two formulations of (2,4,5-T) acetic acid. 57 p. with 3 appendices.

Seven fish species raised in aquaria received repeated exposures of two 2,4,5-T formulations.

Large mouth bass (Micropterus salmoides), white crappie (Pomoxis annularis), black bullhead catfish (Ictalurus melas), channel catfish (Ictalurus punctatus), and a green-redear sunfish hybrid (Lepomis cyanellus-L. microlophus) were exposed to the triethylamine 2,4,5-T formulation. Two other species, sharpnose shiners (Notropis oxyrhynchus) and red shiners (Notropis lutrensis) were exposed to the isooctyl ester 2,4,5-T formulation. Treatment levels ranged from 25 to 400 p/b, number of exposures varied from 2 to 9, while time between exposures was 2 to 5 weeks. Duration of the experiments was 9 to 18 weeks. Treatments were not shown to be responsible for mortalities or differences in growth. Some 2,4,5-T residues accumulated in tissues of most of the fish species tested. No dioxin residues were found in any fish tissues.

Research Agreement 16-695-GR
Texas Tech University
John D. Garcia, Principal Investigator

McGee, John M. IV-5
1976. The immediate effects of prescribed burning on the vertebrate fauna in a sagebrush-grassland ecosystem on Burro Hill, Bridger-Teton National Forest, Wyoming. 69 p.

The purpose of this study was to determine the immediate changes in species composition, density, and biomass of birds and mammals following spring and fall burning in a sagebrush-grassland ecosystem. The major results indicate that there is an increase in the use of burned areas by nonbreeding and predator birds following the burn and a decrease in use by breeding birds. Mammal use of the burned areas increased in the second growing season following the burn, with deer and Uinta ground squirrels predominating.

The report gives detailed information on use by other birds and mammals for the various vegetation types and periods of time following the burn.

Research Agreement 16-376-CA
University of Wyoming
John M. McGee, Principal Investigator

Molles, Manuel C. IV-6
1979. Recovery of stream benthos from disturbance resulting from a natural flood. 10 p. plus 2 tables and 4 figures.

In mid-August 1977, a flash flood disrupted the benthic community of one of two forks of Tesuque Creek, Sante Fe National Forest, New Mexico. This study of the disturbed stream was undertaken to (1) determine the rate of recovery of the benthos, and (2) compare the rates of recovery of benthos upstream and downstream from the undisturbed fork of Tesuque Creek.

One year after the flood, no significant differences were detected between flooded and unflooded sites in biomass, numbers of individuals, or numbers of species. However, some differences in composition of the benthos remained. The Trichoptera and Coleoptera appeared to recover most slowly from the effects of the flood. It is suggested that these two orders may be useful as indicators of the flow stability of streams. Recovery appeared to proceed at approximately equal rates upstream and downstream from the undisturbed fork.

Research Agreement 16-705-GR
University of New Mexico
Manuel C. Molles, Principal Investigator

Renwald, J. David, Jerran T. Flinders, and Henry A. Wright. IV-7
1976. Effect of prescribed fire on bobwhite quail habitat and population dynamics in the Rolling Plains of Texas.

This study was conducted from 1973-1975 to determine the effects of a 7-year burning program on bobwhite quail habitat. It was found that quail preferred lotebush as loafing cover over all other woody plants, although honey mesquite was also used during the summer months. Most of the lotebushes on the study area were resprouts of burned plants. During the first 5 to 6 years after burning, quail used large lotebushes that had escaped fire or were partially defoliated. Following fire, only 3.9 lotebushes per ha were available as cover for quail. Little covey movement was observed between seasons, indicating yearlong cover requirements were being met within a fairly small area. Before burning large pastures, at least 10 large honey mesquite and four large lotebushes per ha should be ringed with 7-m firebreaks to insure adequate cover for quail.

Research Agreement 16-457-CA
Texas Tech University
Henry A. Wright, Principal Investigator

Published as Eisenhower Consortium Journal Series Paper 16. Renwald, J. David, Henry A. Wright, and Jerran T. Flinders. Effect of prescribed fire on bobwhite quail habitat in the Rolling Plains of Texas. Journal of Range Management 31(1):65-69, 1978. Also resulted in publication of: Renwald, J. David. Effect of fire on lark sparrow nesting densities. Journal of Range Management 30(4):283-285, 1977.

Roppe, Jerry A. IV-8
1974. Effects on wildlife of a fire in a lodgepole pine forest. 100 p. (M.S. thesis).

Effects of a subalpine wildfire on populations of wildlife were investigated 8 years after

the Comanche burn in north-central Colorado. The study identified and evaluated the effects of Comanche burn on the following parameters of wildlife of the area: species composition, species diversity, abundance, and distribution. Inventories of birds, small mammals, and large mammals were compared on the burn with those from adjacent similar sites of unburned lodgepole pine.

Relative abundance and values of standing crop biomass for birds, small mammals, and large mammals were higher on the burn than in the lodgepole. Consuming biomass and the efficiency of food utilization for avifauna were higher on the burned area. However, fecal counts for hare indicated higher use in the lodgepole pine and, therefore, estimated values of total biomass for all wildlife were similar for both habitats.

Eight years after the fire, wildlife on the burn was as abundant as in the adjacent lodgepole pine, although differences in species composition were evident.

Research Agreement 16-373-CA
Colorado State University
Dale Hein, Principal Investigator

Roppe, Jerry A., and Dale Hein. IV-9
1975. Effects of fire on wildlife in the Rocky Mountains: A Review. 43 p.

A review and evaluation of literature was conducted on the effects of fire on wildlife in the montane forests of the central Rocky Mountains. Selected pertinent information from other regions and effects of other disturbance activities such as logging are included. The responses of wildlife parameters to fire are described and the effects of fire on wildlife are summarized. Recommendations for future wildlife-fire research are made.

Research Agreement PO 543-RM-00-74
Colorado State University
Dale Hein, Principal Investigator

Steinhoff, Harold W. IV-10
1979. Analysis of major conceptual systems for understanding and measuring wildlife values. 39 p. with 8 tables and 5 appendices.

This study was a literature analysis of the current state of knowledge on understanding and measuring wildlife values. It attempted to bring together several approaches as a basis for a single comprehensive system for describing wildlife values. The study resulted in ranking the usefulness of various methods for assessing wildlife values by categories of values and use of end product.

Research Agreement 16-887-GR
University of Arizona
Ervin H. Zube, Principal Investigator

Additional information on wildlife may be found in the following abstracts: II-7, II-21, II-31, and VII-7.

V. Social and Economic Effects

Beiswenger, Ronald E., and Alfred A. Arth. V-1

1976. Providing awareness relating to non-damaging movements to, through, within, and from wildland areas.

The research was involved in developing methods for increasing user awareness of environmental aspects of recreation use of forest lands. The report describes the materials used in evaluating awareness and measuring the effectiveness of the measurements. Kits have been developed for use by educators.

Research Agreement 16-458-CA
University of Wyoming
Ronald E. Beiswenger, Principal Investigator

Chase, David D., and Theodore A. Hoff. V-2

1974. An analysis of incremental costs to the United States Forest Service resulting from recreational developments on adjacent private lands along the Mogollon Rim area of Arizona. 30 p.

A statistical model was developed to estimate the costs to the USDA Forest Service of increased utilization of adjacent private lands for recreation and second-home development. The model was then used to analyze the impacts of such developments on the public lands in the Mogollon Rim area.

The analysis showed that such developments on private lands significantly increased public land management costs, and it was recommended that new budget processes be instituted to show these cost increases in financial planning and that the USDA Forest Service be more active in land use planning off public lands.

Research Agreement 16-347-CA
Northern Arizona University
David D. Chase, Principal Investigator

Published in Eisenhower Consortium Bulletin 1 as Cost to public land agencies resulting from recreation developments on adjacent private lands, p. 86-92.

Gum, Russell L., and William E. Martin. V-3

1975. Future demands for outdoor recreation. 24 p.

Static demand curves for outdoor recreation may be estimated quite efficiently from cross sectional data using the general Clawson-Hotelling approach. This approach gives demand curves that relate alternative quantities taken to alternative costs for each quantity when costs are measured in both dollars and distance. But this approach has not proven successful in defining the important variables that would cause the static demand curves to shift to the right or left over time and allow projections of future demand to be made. The reason for this lack of success has been demonstrated in this paper.

Various groups of people react in different ways to the same set of variables. For example, high income allows high participation, but it is associated with both high participation by one group and low participation by others. Lack of money and lack of time are important to some people, but the most important shifter variable for the great majority of people is simply their "tastes and preferences" for outdoor recreation versus other alternatives. All people tend to react to changed cost and/or distance at any point in time, but most people would change this reaction pattern only in response to changed attitudes rather than in response to more simply measured variables such as income. Further, it is implied that each type has a very differently shaped demand curve for outdoor recreation than does any other type at any given point in time.

This study has given insights into how current attitudes affect the behavior of the different types of households within Arizona with respect to participation in outdoor recreation. But before much can be known about future demand, much more must be known about the rate and distribution of how attitudes toward hunting, fishing, and general rural outdoor recreation are changing.

Research Agreement 16-283-CA
University of Arizona
William E. Martin, Principal Investigator

Published as Eisenhower Consortium Journal Series Paper 8, Structure of demand for outdoor recreation. Land Economics 53(1):43-55, 1977.

Hoff, Theodore A., and Timothy G. Shahen. V-4

1975. Local socioeconomic effects of subdivision developments in rural areas of Arizona. 25 p.

Vacation or second home subdivisions around Flagstaff, Ariz., were studied to determine changes in subdivision use and growth over time, and the impacts of these developments on local economies. It was found that rural subdivision developments do go through an evolutionary process, so research must consider these developments through time rather than at one point in time.

Because of this evolutionary process, local governments must make adjustments when planning future increases in government services. The time lag between initial revenue generation and later increase in demands for government services must be recognized if an orderly development of government services is to occur.

Research Agreement 16-452-CA
Northern Arizona University
Theodore A. Hoff, Principal Investigator

Hogan, Timothy D. V-5
1977. Second-home ownership in northern Arizona: A profile and implications for the future. Eisenhower Consortium Institutional Series Report No. 2, Bureau of Business and Economic Research, Arizona State University, Tempe. 113 p.

This report presents the findings of a survey of 306 owners of second homes in five areas in northern Arizona. The survey data provides information not previously available detailing a wide variety of characteristics of second-home-owner's households, of their attitudes, utilization of the properties, and of their second homes. The study examines the pattern of second-home development in northern Arizona and considers the implications of the survey findings with respect to the characteristics of future development. The report also discusses the implications of such continued development upon the need for improvement and expansion of a variety of facilities and services in the second-home areas.

Research Agreement 16-285-CA
Arizona State University
Timothy D. Hogan, Principal Investigator

Montague, Peter. V-6
1975. At the edge of wilderness: Evaluating environmental and socioeconomic costs and benefits of leisure home developments near national forests in the Southwest. 223 p.

The report presents a detailed evaluation of the socioeconomic and environmental effects of various developments and indicates those areas where regulation of planning would have prevented adverse effects or enhanced benefits. A system is developed to insure more complete analyses on site, developmental design, and public and private costs or benefits. Policies and regulations needed to minimize problems and maximize benefits from developments are outlined.

Research Agreement 16-360-CA
University of New Mexico
Peter Montague, Principal Investigator

Morgan, James N. V-7
1978. Economic and ecological impacts of second home developments on local areas. 60 p. including 3 appendices.

A census of second homes indicated there are 1,352 second homes in the Flagstaff trade area, approximately 10% of the number of primary residences. However, second homes are estimated to contribute only 2% to 2.5% of the area's average population year round, while they may contribute as much as 8% to 10% during peak summer use.

Average total spending per second home was $1,535; a spending level of $5.37 per person day of second home use. Utilities accounted for a large proportion of spending by second home owners.

Over half of the second homes had septic tanks for liquid waste disposal, while less than 7% had no liquid waste disposal system. Over half the owners had to personally remove solid waste from their second home site, but less than 10% felt that solid waste facilities were inadequate to protect the environment.

Energy use per second home averaged only about 16% of the household energy use of a full-time residence. Second home energy use in the study area was estimated to be less than 2% of total residential energy use.

Second homes provide a positive impetus to the area's economy. The most significant negative factor is the strong seasonal use pattern. No strong evidence of inadequate waste disposal facilities was found, although a significant minority of homeowners felt solid waste disposal facilities were inadequate.

Research Agreement 16-597-GR
Northern Arizona University
James N. Morgan, Principal Investigator

Ostheimer, John M. V-8
1975. The Forest Service meets the public: Public involvement experiences of the Coconino National Forest. 84 p.

Public involvement experiences of the Coconino National Forest were examined to identify techniques and events that seem related to successful or unsuccessful public involvement. The report first outlines specific case studies ranging from general planning issues such as land use and multiple use plans, through selected aspects of routine management planning as timber cutting and land exchange programs, to very specific management problems. Then, it discusses the public involvement aspects and experiences involved in the case studies. The specific lessons drawn from each case are analyzed.

Research Agreement 16-453-CA
Northern Arizona University
John M. Ostheimer, Principal Investigator

Published as Eisenhower Consortium Bulletin 5, The Forest Service meets the public: Decision-making and public involvement on the Coconino National Forest, 24 p. 1977.

Parker, Alfred L. V-9
1978. The economic consequences of industrial and residential development as they affect water quality in the southwest. 152 p.

The objectives of this study were to determine the economic consequences of development on water quality. This would involve (1) identifying patterns of land use, (2) matching patterns of use with classifications of land areas, and (3) identifying benefits and costs of use patterns on sensitivity of these areas to these uses. This study was conducted as part of the Southwest Region Under Stress Program of the University of New Mexico and Resources for the Future. The results are as follows:

1. Models were developed and tested to project visitation at water-based and land-based recreation sites. The major models were found to give statistically reliable projections and can be used to plan needs to meet future demands.
2. A computer-mapping technique was developed which, when combined with visitation projections, can provide information on the impact of energy resource development in existing and potential recreation sites and indicate areas of excessive population impacts.
3. Attempts to estimate willingness to pay for environmental quality from property value studies were unsuccessful. Moreover, with absolute irreversibility and indivisible environmental quality, existing decision-making procedures may be biased against preservation and in favor of land development.

Research Agreement 16-567-CA
University of New Mexico
Alfred L. Parker, Principal Investigator

Robinson, Charles F. V-10
1975. Goals, values and problems of mountain residential landowners. 79 p. (M.S. thesis).

Interviews with 103 small landowners in a Colorado mountain watershed indicated that they had purchased the land for recreational use and prized it for its scenic aspects, privacy, access, and recreational opportunities; over half expected to build cabins in the area.

The landowners perceived the existence of nearby USDA Forest Service lands as an aid in keeping the area in its natural state, but they also blamed poor road conditions, high traffic volume, and poor facilities on inadequate attention by the USDA Forest Service, county governments, and "outsiders."

Most landowners wanted to limit development to cabins only and felt that it would be best to limit the number of cabins. Except for electricity and road maintenance, few landowners desired much in the way of services.

Research Agreement 16-287-CA
Colorado State University
R. B. Held, Principal Investigator

Published in Eisenhower Consortium Bulletin 1, as Held, R. Burnell, and Charles F. Robinson. The mountain property owner: His values, goals, and problems, p. 93-97.

Shahen, Timothy, and Theodore Hoff. V-11
1977. Analysis of forest use by rural subdivision residents. 27 p.

The study was designed to test two specific hypotheses: first, urban residents generally use the forest facilities less frequently than do the residents of rural subdivisions; and second, residents of large rural subdivisions use the forest less than residents of small rural subdivisions because the large subdivisions provide more on-site recreation facilities. In addition to these two hypotheses, an attempt was made to determine if forest use was affected by either family socio-economic characteristics or subdivision characteristics.

First, it was found that, contrary to the original hypothesis, city dwellers use the forest more frequently than rural subdivision residents. Second, there were no significant differences in usage by large versus small rural subdivision residents. That is, the degree to which rural subdivisions provide on-site recreation facilities does not affect forest use. Third, for rural subdivision residents, those families purchasing the lot primarily for recreation purposes used the forest more frequently than those families who purchased lots for other reasons. Lastly, of those socio-economic family characteristics provided by questionnaire respondents, only family size was an important determinant of forest use. Families with two small children used forest facilities most frequently.

The results of this study should be widely applicable to areas with urban-rural distributions similar to those in northern Arizona. It appears that the resident city population is relatively more important for long range forest management planning.

Research Agreement 16-530-CA
Northern Arizona University
Timothy Shahen, Principal Investigator

Walsh, Richard G., Michael F. Retzlaff, and Eliot O. Waples. V-12
1975. Economic implications of second-home developments in selected areas of Colorado. 10 p.

Costs and benefits of condominium ownership at three Colorado ski areas were estimated on the basis of a sample survey in 1974. Costs of owner use under recent inflationary conditions were $37 per day compared to rental rates of $32. Under stable investment values, owner costs would rise to $59 per day. If investment values fall 5% annually, costs would rise to $103 per day of owner use.

Research Agreement 16-363-CA
Colorado State University
Richard G. Walsh, Principal Investigator

Published in Eisenhower Consortium Bulletin 1, p. 98-107.

Young, Kenneth B., and Mesbah U. Ahmed. V-13

1976. Costs and effectiveness of selected alternative second-home waste disposal systems applicable to west Texas conditions. 252 p.

Inadequate treatment of wastewater from recreational areas is a major source of pollution in public waters. Many recreational areas are developed with individual disposal units for waste water treatment which subsequently become inadequate with continued population growth.

The impact of more stringent federal and state air and water quality standards together with mounting water demands to serve domestic, industrial, and agricultural needs have provided a strong incentive to reevaluate existing treatment systems and to promote more beneficial reuse of wastewater. Reuse of treated effluent can be expected to attain greater economic significance over time as conventional water supply sources become more limited.

In this study, an intertemporal simulation model is developed to determine the least-cost decision rule with respect to the following four classes of wastewater disposal decisions for a recreational area: (1) collection methods, (2) central treatment methods, (3) irrigation methods, and (4) selection of alternative irrigation sites and desirable vegetation to be irrigated. Results of using alternative disposal methods are simulated from 1975 to 1995 to identify interactions between system components and to evaluate economics of the overall sewer project.

The major findings in the analysis are that additional permit sales generated at lake sites from irrigation development would offset at least a major part of system costs, and that proposed central sewage projects may be economically feasible when compared with the alternative of individual septic tank installations.

Research Agreement 16-348-CA
Texas Tech University
Kenneth B. Young, Principal Investigator

Published in Eisenhower Consortium Bulletin 1, p. 202-212.

Additional information on social and economic effects may be found in the following abstracts: VI-2, and VII-5.

VI. Management Activities

Allen, Debora J., and Richard Shikiar. VI-1
1979. Visitor use and preference study: Oak Creek Canyon, Arizona, 1977. 26 p. plus 7 appendices.

Research conducted in 1977 indicates that Oak Creek Canyon is not the major trip destination for most of the users; it is most often part of a trip to somewhere else. However, the closer a user's residence to the canyon, the more likely that the canyon is the major trip destination. Thus Oak Creek Canyon is more likely to be a major trip destination for Arizona residents.

Users indicated support for more public land acquistions and development and were in favor of limited restrictions on use to preserve water quality and scenic beauty. However, most opposed any actions that might curtail their activities.

The study concluded that Oak Creek Canyon provides unique recreation opportunities in Arizona. Visitors are primarily from urban areas who are attracted to the area by the magnificent scenery. Maintenance of the scenic beauty and water quality should be given top priority. The scenery-naturalness of Oak Creek Canyon that is desired by recreationists should also be used to temper the demands for more facilities if these developments would impair the scenic quality.

Research Agreement 16-731-GR
Colorado State University
Richard Shikiar, Principal Investigator

Bond, M. E., and Robert H. Dunikoski. VI-2
1977. The impact of second-home development on water availability in north-central Arizona. Bureau of Business and Economic Research, Arizona State University, Tempe. Eisenhower Consortium Institutional Series 1, 88 p. 1977.

Second homes in the study area have increased from 5,553 in 1967 to 10,545 in 1975-76; over 10% per year. Forecasts indicate an inventory of 15,800 second homes by 1980 and 21,100 by 1985.

Water consumption for the 10,545 homes was estimated to be 263,625,000 gallons in 1974, about 0.2% of municipal and industrial water used in Arizona.

Based on water usage per home, the availability of water in the study area should not be a deterrent to second-home development. The water will come from wells to a plentiful ground water supply, but there may be localized shortages.

Sampling and projection techniques are described in the report.

Research Agreement 16-517-CA
Arizona State University
M. E. Bond, Principal Investigator

Buchanan, Jacquelin P. VI-3
1978. A financial feasibility analysis of public and private campground development in the greater Yellowstone Grand Teton area. 111 p. including 3 appendices. (M.S. thesis).

Breakeven fee schedules are developed to determine the financial feasibility of public and private campgrounds in the area, stressing the importance of the cost of land on the feasibility issue.

The feasibility schedules developed for both the private and public campgrounds show a discrepancy between the fees charged by public and private operators and the fees that would be required to meet the full costs of developing and operating campgrounds. Because the fees charged by the public agencies were not even half the average private campground fees, the discrepancy was even greater for the public sector.

Research Agreement 16-654-GR
University of Wyoming
Clynn Phillips, Principal Investigator

Burford, Charles L., James D. Mertes, and Tom W. Jones. VI-4
1976. Technological and environmental planning considerations to minimize the environmental impacts of transporting people and products through wildland areas. 173 p.

The study found that, while federal and state land managing agencies are interested in alternative systems for transporting people through wildland areas without adverse environmental impact, the private automobile will continue to be the main method of transportation in wildlands. Under certain circumstances, mass transportation can be used to replace the automobile. However, the development of a mass conveyance system depends on stable high-density usage throughout the year, with key facilities being clustered at points along the route. The study notes that the usual urban mass transportation systems are not adaptable to wildlands, and that the more exotic forms which impact least on the environment are very expensive. The study presents a good review of the current planning and engineering thinking in this area, as well as several case studies of applications of mass conveyance systems in wildland areas.

Research Agreement 16-455-CA
Texas Tech University
Charles L. Burford, Principal Investigator

Published in part in Eisenhower Consortium Bulletin 1 as: Burford, Charles L., and Tom W. Jones, III. Transportation system planning for wildland areas, p. 157-163.

Burford, Charles L., Larry E. Page, and James D. Mertes. VI-5

1978. Development, trial application and evaluation of a transportation mode alternative analysis and specification selection procedure for use in wildland transportation planning. 272 p.

The principal result of this study is the development and field testing of the specification selection procedure for analyzing transportation alternatives for consideration in wildland areas. A good deal of the background was developed under Research Agreement 16-455-CA, Technological and Environmental Planning Considerations to Minimize the Environmental Impact of Transporting People and Products Through Wildland Areas: An Overview, by C. Burford, J. Mertes, and T. Jones.

The specification selection procedure, when used in conjunction with the factor profile analysis technique, provides a reliable approach to analyzing wildland transportation problems and selecting a viable alternative. The factor profile analysis allows the display of all key factors used in the assessment of each potential transportation alternative. The report suggests a simple procedure for conducting an economic and financial analysis of candidate alternatives.

The procedure developed in this study can be modified to accomodate the wide range of transportation problems confronting wildland planners and managers.

Research Agreement 16-523-CA
Texas Tech University
Charles L. Burford, Principal Investigator

Doehring, Donald O., and Frank G. Ethridge. VI-6

1979. Estimating coarse sediment transport in mountain watersheds. 34 p. with 4 tables and 11 figures.

The research reported here was conducted to: (1) develop a procedure for estimating sediment discharge given hydrologic, morphometric, and sedimentologic inputs; (2) estimate the median bedload size moved by floods of various return periods; (3) develop the capability to estimate bedload sediment movement for given grain sizes under given hydrologic conditions; and (4) test the applicability of the Pfankuch-Rosgen channel stability technique for estimating sediment yield in the Roosevelt and Medicine Bow National Forests.

It was found that:

1. The equation developed on the Little South Fork of the Cache la Poudre River consistently underpredicts on streams where there is a large amount of glacial sediments. These unconsolidated sediments seem to increase the sediment available to the stream by a process which is underestimated or unexplained by the morphometric variables of the models.

2. Mean grain size (in phi units) of bedload can be estimated for the lower, nonglaciated reaches of the South Fork, by Mz = 0.55 - 0.0031 Qw; maximum bedload sizes by, Max = -1.637 - 0.0046 Qw. For the upper glaciated reaches, Mz = 0.330 -0.01133 Qw.

3. The Pfankuch-Rosgen channel stability rating method (Pfankuch 1975) for evaluating the production of bedload was applied through the use of Spearman Rank Correlation. The Spearman Rank Correlation was sufficiently high to conclude an association between channeled stability and normalized sediment discharge. This correlation between channel stability rating and observed bedload transport indicates that the channel rating method is applicable to the South Fork of the Cache la Poudre and, in all likelihood, to similar streams in the Rocky Mountain Front Range.

Research Agreement 16-692-GR
Colorado State University
Donald O. Doehring, Principal Investigator

Flack, J. Ernest. VI-7

1976. Assessment of water and wastewater design criteria for new towns. 12 p.

The purpose of this project was to make an analysis of the design criteria for rapid growth areas and resorts under the sometimes severe climate and flow conditions of the Rocky Mountain forest environments. Available technologies and research results were scrutinized for their applicability and a design treatise was developed for research users. Three publications resulted: "Proceedings of a workshop on design of water and waste water systems for resorts and boom towns," J. Ernest Flack, editor; "Water and waste water systems for rapid growth areas and resorts," M.S. thesis by Paul J. Gorder, University of Colorado; and "Design of water and wastewater systems for rapid growth areas," by J. Ernest Flack, Environmental Resources Center, Colorado State University.

Areas of needed research were delineated for improving design.

Research Agreement 16-521-CA
University of Colorado
J. Ernest Flack, Principal Investigator

Freeburg, Robert S., and Bruce A. Buchanan. VI-8

1976. Impact of roads in recreational developments on forest environments. 20 p.

Recreational developments and the second home are increasing in popularity. Erosion was found to be approximately five-fold greater soon after a road was completed and during periods of home excavation and construction than for the undisturbed forest.

Forests appear to buffer the adverse results of construction, but during construction when the erosion potential is greatest, efforts should be made to provide sediment traps to minimize this erosion. Also, careful planning so as to place trunk roads on contours and reduce long road sections will diminish the detrimental effects of construction.

Research Agreement 16-423-CA
New Mexico State University
Robert S. Freeburg, Principal Investigator

Gerking, S. D., Christopher J. Holmes, and Melissa van Brackle. VI-9
1979. A short term forecasting model for second homes in northeastern Arizona. 38 p.

The report presents a simple method for predicting the future number of second homes in a given area. Local planners can use it to reduce unwanted side-effects from second home construction when their probable numbers are known in advance. The forecasting method is based upon a Box-Jenkins type of univariate-time-series-extrapolation of seasonal residential electrical-utility connections. These utility connections served as a proxy variable for the number of second homes. The method, which is illustrated using data from Navajo and Apache Counties in Arizona, can provide forecasts that are within acceptable statistical error limits.

Research Agreement 16-699-GR
Arizona State University
Shelby D. Gerking, Principal Investigator

Hasfurther, Victor R. VI-10
1975. Suitability of an evapotranspiration waste disposal system for selected semi-primitive mountain environments during the winter. 47 p.

An evapotranspiration system was operated during the fall, winter, and spring in Wyoming. During the summer months the system would handle a loading of 1,000 to 1,500 gallons per week, but the loading capacity declined during the fall and winter. At the first hard freeze, the acceptable loading rate declined to between 150 and 500 gallons per week. When the entire unit freezes over, the input must be reduced to 100 gallons or less per week with a zero inflow the safest situation in January and February. As the weather warms up in the spring, loading may be increased, but for Laramie, it should not exceed 500 gallons per week until mid-May.

Research Agreement 16-460-CA
University of Wyoming
Victor R. Hasfurther, Principal Investigator

Published in part as Eisenhower Consortium Bulletin 6, Hasfurther, Victor R., and David H. Foster. Operation and design of evapotranspiration waste disposal systems, 21 p. 1978.

Hasfurther, Victor R., Douglas Lofgren, and Stephen R. Jenkins. VI-11
1974. Analysis of suitability of evapotranspiration waste systems for selected semi-primitive mountain environments. 40 p.

The effectiveness of an evapotranspiration waste system was tested during the summer months at loads between 100 and 300 gallons per day. It was found that the unit was as efficient as any other typical secondary effluent treatment system, the cost of the unit compares favorably with septic tank-lead field systems, and the operating costs are essentially zero. The unit treats sewage by anaerobic processes so it can be installed in an esthetically pleasing way. There is essentially no odor generated.

The study did not analyze the operation of the unit during periods of freezing weather.

Research Agreement 16-354-CA
University of Wyoming
Victor R. Hasfurther, Principal Investigator

Published in part in Eisenhower Consortium Bulletin 1 as, Hasfurther, V. R., D. H. Foster, D. G. Lofgren, and S. R. Jenkins. Evapotranspiration as an alternative for second home waste disposal systems. p. 213-220. Also published in part as, Hasfurther, Victor R., David H. Foster, and Glenn D. Lloyd. 1978. Sizing an evapotranspiration waste disposal system for summer operation. p. 175-184. In Proceedings of the second national home sewage treatment symposium, Dec. 12-17, 1977, Chicago, Ill. American Society of Agriculture Engineers Publication 5-77.

Hedstrom, Warren E., Larry O. Pochop, and Darryl D. Alleman. VI-12
1974. Analyses of suitability of closed-system waste disposal for recreation facilities in selected semiprimitive mountain environments. 22 p. (typed).

The effectiveness of a two-cell aerated lagoon system for treatment of vault toilet wastes in the Medicine Bow National Forest of Wyoming was investigated through use of on-site pilot lagoons. Results indicate that BOD was reduced by over 99%, with the resulting effluent having very little turbidity, odor, or color. Raising the operating temperature of the first cell by 8° to 15° C did not significantly change the lagoon's BOD removal efficiency or the quality of the effluent when the system was operated for only 30 to 35 days. Irrigation of the effluent onto soil columns with growing native plants caused marked increases in growth rates with no noticeable adverse effects and little hazard of ground water contamination. The design and intended operating procedure of the actual lagoon appear to be sound.

Research Agreement 16-353-CA
University of Wyoming
Warren E. Hedstrom, Principal Investigator

Published as Eisenhower Consortium Journal Series Paper 2, Alleman, Darryl D., et al. 1975. Pilot plant study of a treatment system for recreational area vault toilet waste. Journal of Water Pollution Control 42(2):377-385.

Hogan, Timothy D., M. E. Bond, and Robert H. Dunikoski. VI-13
1979. Streamflow and second-home development in northern Arizona. Eisenhower Consortium Institutional Series Report No. 4, 71 p.

This study was initiated to examine the relationship between second-home development and patterns of surface runoff in affected watersheds. In particular, it appears that the volume of stream discharge is increased as second-home developments reallocate utilization of the land from one production form to another. However, a positive relationship was found only after the data series were seasonally adjusted. The estimated magnitude of the impacts and the statistical precision of the relationships are not overly strong.

The report recommends that:

1. More study be undertaken to improve measurements and data series on streamflow and second-home development.
2. More orderly planning for second-home development be undertaken to maximize social and economic benefits.
3. More study be undertaken for a broader geographical basis of conclusions to be used in planning.

Research Agreement 16-787-GR
Arizona State University
M. E. Bond, Principal Investigator

Hughes, William C. VI-14
1976. Rock and riprap design manual for channel erosion protection. 149 p.

The purpose of this manual is to complete the available design information for either riprap or wire-bound rock channel linings and energy dissipators into a usable design format by presenting much of the design information in graphical form. The manual is intended to supplement standard hydraulics texts and manuals, and assumes the user is acquainted with the methods of open channel hydraulics and hydraulic design. Each chapter covers a different aspect of erosion protection using rock and wire-bound rock, with a brief description of the design method at the beginning of the chapter, followed by several example problems.

Research Agreement 16-525-CA
University of Colorado
William C. Hughes, Principal Investigator

Jones, Daniel Bernard. VI-15
1975. An optimizing reservation system for back country campsites. 137 p. (M.S. thesis).

Increased demand on wilderness areas has prompted research on carrying capacity of recreation areas and on ways of controlling recreation use. The optimizing reservation-permit system developed here is an automated system which can cancel or confirm previous reservations and schedule one or more camper parties for trips according to criteria specified by the requesting party of wilderness managers.

The system was designed for use in Rocky Mountain National Park, but can be adapted to other areas. A dynamic goal programming technique is used to optimally allocate camper parties to camping areas according to four goals: (1) to attain maximum capacity utilization, (2) to minimize the number of areas repeated on a trip, (3) to match camper preferences to activities available in various camping areas, and (4) to reduce impact on individual areas and provide solitude.

An example is presented.

Research Agreement 16-465-CA
Colorado State University
Warren E. Frayer, Principal Investigator

King, David A. VI-16
1974. A review of some planning philosophies and Region 3's guide to land use planning. 23 p.

Concepts in land use planning are reviewed and the USDA Forest Service Southwest Region guide to land use planning is described. A comparison is made between the guide and a linear programming model developed for use in the Salt-Verde River Basin. Limitations of the guide are noted, and the advantages of the model in land use planning are outlined. Use of the linear programming model would provide the needed interface between land use planning and resource planning.

Research Agreement 16-282-CA
University of Arizona
David A. King, Principal Investigator

Lee, Robert W., R. H. Ramsey III, and L. V. Urban VI-17
1978. Environmental guidelines for second home developments in mountain areas. Eisenhower Consortium Institutional Series Report 3, and WRC 78-1. Texas Tech University, Lubbock. 125 p.

The guidelines developed in this study incorporate 34 environmental parameters in the areas of esthetics, air, land, water, and socioeconomics, and 141 activities associated with the planning, construction, and occupancy of second-home developments. A matrix format is developed to relate activities to potential impacts and utilized to summarize appropriate management strategies involving police power, eminent domain, taxation, and permit powers of state and local governments. These environmental guidelines can best be incorporated into second-home development activities through modifications to existing land use controls at the local government level.

Research Agreement 16-528-CA
Texas Tech University
Ralph H. Ramsey III, Principal Investigator

Mertes, James D., Garry E. Carruthers, and Kathryn Renner VI-18
1973. Regional environmental management in west Texas and eastern New Mexico. Resource problems and resource opportunities. 189 p.

The western Texas-eastern New Mexico region is complex and diverse, consisting of mountain ranges, plains, and Chihuahuan desert. It is rich in historical, cultural, and archeological resources, blending the Anglo, Mexican, and Indian cultures.

Water is the major limiting factor for development within the region, and climatic factors inhibit outdoor recreation. While hunting is increasing, most of the recreation-related developments are near the more spectacular natural features and adjacent to public ownerships.

Land use planning is not well developed in the region, and counties have little or no power to plan or regulate land use. The development of recreational communities, especially those catering to retired citizens, is creating new demands on existing economic and social systems which are not adapted to handle them. New service delivery systems are beginning to emerge, but the process is slow.

Opportunities exist to expand recreation opportunities and improve regional development. However, changes will be required in water allocation priorities, public land policies, public involvement in planning, and present county land-use-planning systems if development is not to have significant adverse effects on the environments. Selected changes are suggested.

Research Agreement 16-284-CA
Texas Tech University
James D. Mertes, Principal Investigator

Mings, Robert C., Wayne V. Balmer, and Martin E. Wurks. VI-19
1976. An exploratory study of opportunities for improving solid waste collection in outdoor recreation areas of the Tonto National Forest in Arizona. 18 p. plus 3 appendix tables and 7 appendix figures.

The collection system employed on the Tonto National Forest is effective in emptying established receptacles and gathering large scattered pieces of debris. However, the system fails to collect smaller items discarded outside of established receptacles, so this litter is accumulating.

The report analyzes litter buildup by recreation area, intensity of use, and level of litter. Recommendations are made to prevent excessive litter buildup and to increase collection efficiency.

Research Agreement 16-286-CA
Arizona State University
Robert C. Mings, Principal Investigator

Rasmussen, William O. VI-20
1978. Development of a corridor selection system for forest road location planning. 26 p. including 10 figures and 2 tables.

A methodology for incorporating economic and esthetic criteria within a forest-road corridor selection process is described. The methodology utilizes computer graphics techniques to store, analyze, and display information needed for corridor decisionmaking. Costs are based on an accounting of the total dollar costs of each alternative. Scenic beauty estimates, based on a systematic public participation process, are used to quantify esthetics. Trade-offs between economic and esthetic factors are readily displayed by developing corridor alternatives based on both economic and esthetic criteria. Although objective procedures are used to quantify economic and esthetic impacts, human judgment is still required to assign relative importance to alternative criteria before the maps are composited in the production of a suitability surface for a recreational road.

A technique has been presented to delineate a path between two terminal points in a spatial data array representing some combination of economic and scenic beauty costs of road construction.

Research Agreement 16-526-CA
University of Arizona
William O. Rasmussen, Principal Investigator

Segall, Burton A., and William E. Vins. VI-21
1976. Wastewater treatment and disposal for second homes and low density resort development. 181 p.

This research was undertaken to evaluate various vacation home wastewater treatment and disposal systems, develop a selection procedure, and indicate innovative techniques for further research.

It was found that, because of low density of population, the per unit costs of central sewage systems in vacation homes is quite high and operations and maintenance are quite poor. Central systems should be as foolproof and maintenance free as possible. In fact, individual systems may be the best.

Present systems, based on water transpiration, are adequate but dependent on soil type treatment process to improve health protection. Reuse of waste water in the sewage systems should be considered. Details are given on selection requirements.

Research Agreement 16-527-CA
Arizona State University
Burton A. Segall, Principal Investigator

Trotta, Paul D. VI-22
1979. Impact of development on stream flow. 50 p. with 11 tables, 4 figures, and 1 appendix.

This report presents the findings of a study intended to identify the long-range effects of development upon stream flow. The study has attempted to identify the hydrologic parameters most affected by the development of rural forested watersheds into second-home and resort-type communities. Once identified, the parameters selected were changed from their original values to values which reflect a variety of development levels ranging from undisturbed watershed up through complete suburban development with housing densities as high as one house per quarter acre. A computer simulation was then used to predict the streamflow for each level of development. The results indicate that such development increased significantly the surface runoff from the waterhsed.

Research Agreement 16-792-GR
Northern Arizona University
Paul D. Trotta, Principal Investigator

Verma, Tika R., and John L. Thames. VI-23
1977. Review of methodology for ecological inventories for planning and managing surface mining operations and after mining rehabilitation. 37 p.

In this study, the general methodology for ecological inventories was reviewed with special emphasis on vegetation. Other topics considered included animal ecology, geomorphology, soils, and water resources. The physiography, climate, flora, fauna, hydrology, and land use on the Black Mesa were discussed and previous studies reviewed. Specific recommendations were made concerning future comprehensive plant life surveys on the Mesa. The results of a brief small mammal study made in the coal lease area were presented, and the appendices include plant and animal species lists for Black Mesa.

Research Agreement 16-448-CA
University of Arizona
Tika R. Verma, Principal Investigator

Walsh, R. G., J. P. Sooper, and A. A. Prato. VI-24
1978. Efficiency of wastewater disposal in mountain areas. Technical Report 10. Environmental Resources Center, Colorado State University, Fort Collins, 92 p.

Model wastewater disposal systems were analyzed by engineering-economic cost methods. Investment costs were found to be 30% to 50% higher than in other areas; physical conditions associated with elevation explain most of the difference in costs. Temperatures, soil permeability, topography, water quality, and labor productivity were the major physical conditions related to elevation, and economic conditions such as higher land values, interest on investment, peak loads, growth rates, and septic tank installation costs were included in the evaluation. The results may contribute to decisions concerning efficient land use. Minimum and maximum levels of land subdivision were shown for typical environmental conditions. Under severe physical restrictions, wastewater transmission costs are prohibitively high. Where septic tanks result in water pollution, development should not be allowed. Under less severe physical conditions, residential development may be encouraged up to optimum community size of about 12,800 people. Optimum size is much smaller than in other areas of the U. S. because transmission costs rise in narrow mountain valleys. Land subdivision which would increase population beyond the optimum level would increase costs per capita and may result in decisions to limit growth.

Research Agreement 16-660-GR
Colorado State University
Richard G. Walsh, Principal Investigator

Additional information on management activities may be found in the following abstracts: II-2, II-12, II-20, II-27, III-7, III-8, IV-5, IV-6, IV-9, IV-11, VII-5, and VII-14.

VII. Fire

Bock, Jane H., Carl E. Bock, and Robert J. McKnight. VII-1
1976. A study of the effects of grassland fires at the Research Ranch in southeastern Arizona. 14 p. plus 11 tables.

The effects of two fires on the Research Ranch near Elgin, Ariz., in the spring of 1974 were studied through two post-fire growing seasons. The grass cover was reduced initially by the fires and the growth of herbs encouraged. After the second post-fire growing season, both burned plots were 90% similar to their respective controls. Thirteen of 19 bird populations were larger on the burned plots than on the controls. Small mammals showed no significant increases on the burns, and in 4 of the 16 cases, showed significant decreases. The flora and fauna of the Research Ranch do not appear to have experienced any permanent alterations as a result of these fires.

Research Agreement 16-474-CA
University of Colorado
Jane H. Bock, Principal Investigator

Published in Arizona Academy of Science 11(3):49-57, 1976.

Covington, W. Wallace. VII-2
1978. The effect of prescribed fire on nutrient cycling characteristics of the ponderosa pine forest floor. 21 p. including 3 tables and 2 figures.

Chemical analyses of the fine fraction of the forest floor showed the organic matter content decreased by 20% as an immediate result of prescribed burning. It decreased by another 20% in the following 8 months (November to June).

Calcium, magnesium, and potassium increased greatly immediately after burning. Calcium concentrations remained about the same, magnesium declined, and potassium increased during the following 8 months. Nitrogen and phosphorus also increased significantly immediately after the fire; nitrogen concentrations returned to pre-fire levels after 8 months.

The additional decrease in organic matter content during the 8 months after the fire, presumably due to accelerated microbial decomposition processes under more favorable conditions, may be especially important, since nutrients mineralized in this manner are released more gradually than the sudden pulse brought about by fire.

It is doubtful that understory burning at the relatively "cool" intensity studied would result in substantial increase in nutrient export in runoff or degradation of water quality.

Research Agreement 16-693-GR
Northern Arizona University
W. W. Covington, Principal Investigator

Fechner, Gilbert H., David V. Sandberg, and Jack S. Barrows. VII-3
1975. Aspen stands as wildfire fuel breaks. 56 p.

Fire ignition rates in quaking aspen stands are less than half of those for all other cover types in Colorado. These stands do not support rapidly spreading or intense fires due to their low burning index and spread component. Crown fires drop to the ground when they reach quaking aspen stands, and prior to autumn leaf fall, fire spreads only a short distance into the stands.

Quaking aspen propagation can be encouraged in the field by severing roots from the main stem; under suitable temperature and light intensity, this stimulates abundant sucker formation. Artificially, quaking aspen can best be propagated through the use of root cuttings.

Research Agreement 16-473-CA
Colorado State University
Gilbert H. Fechner, Principal Investigator

Published as Eisenhower Consortium Bulletin 4, 26 p. 1976.

Fitzhugh, E. Lee, and Jean T. Beaulieu. VII-4
1976. Wildfire effects on plant and animal communities in Arizona ponderosa pine forests. 66 p.

Plant species composition and use by deer, elk, and cattle were monitored after a 748-acre, early-spring wildfire which burned in the ponderosa pine type on limestone-derived soils southwest of Flagstaff, Ariz. Plants which increased or decreased after either severe or moderate intensities of fire were identified. The moderately burned area was similar in species composition to the control (unburned) areas after three growing seasons, but remained much higher in herbage production. The severely burned area showed signs of continued plant succession after three growing seasons. During the year of the fire, there was no detectable difference in herbage production between any of the areas, illustrating rapid recovery of the burned areas. After the third growing season, the severely burned area produced more than the moderately burned area, and both produced much more than the controls. Use of the areas by elk and cattle either could not be tested or differences could be explained by factors unrelated to the fire. Deer use of the severely burned area exceeded the level of the control after 2 years. Deer use of the moderately burned area exceeded that of the control the year of the fire. Deer use of the severely burned area appears to be increasing, while use of the control and, to a lesser extent, the moderately burned area is decreasing. The pattern of use by deer in different years and on different areas appears to be related to the production of highly palatable plants more than to total herbage production. The fire appeared to

be immediately beneficial to deer in moderately burned areas. There was little detrimental effect on deer, elk, or cattle use of any of the burned areas.

Research Agreement 16-454-CA
Northern Arizona University
E. Lee Fitzhugh, Principal Investigator

Goodson, Nike J., and James A. Bailey. VII-5
1976. Forest fuels and esthetic perceptions of owners of second homes in the ponderosa pine zone. 10 p.

Color photographs were taken of ponderosa pine stands. Nine variables of probable importance to fire hazard and scenery were quantified for each photo. Owners of second homes in the ponderosa pine zone rated the projected photos according to their perceptions of scenic quality. Stepwise multiple correlation analysis indicated that standing snags and dead branches and heavy ground fuels were the most important variables affecting scenic quality ratings. Their effects were negative, indicating that programs to remove these kinds of fuels would not detract from scenic quality. The number of trees and abundance of large rocks and shrubs in photos had small but significant effects on scenic quality ratings. Average diameter of trees, light ground fuels, low green vegetation, and live tree branches in the photos did not significantly affect scenic quality.

Research Agreement 16-374-CA
Colorado State University
James A. Bailey, Principal Investigator

Lowe, Peter O. VII-6
1975. Potential wildlife benefits of fire in ponderosa pine forests. 131 p. (M.S. thesis).

Wildfire can be a dominating influence in ponderosa pine forests. Detrimental effects have been emphasized in the evaluation of the impact of wildlife. However, certain wildlife species have been found to benefit from wildfire.

This study was designed to quantify these benefits and develop an index for use in analyses of past-fire values. The study was conducted near Flagstaff, Ariz., with wildlife and habitat components being quantified over a projected 20-year period after the fire and represented as flows of benefits or losses relative to unburned sites.

The results indicate that elk, deer, some rodents, some birds, and forage benefited from fire, while cottontail rabbits, chipmunks, some birds, and ponderosa pine were adversely affected. Annuities were used as indices of benefits or losses and to calculate monetary values of the fire.

Research Agreement 16-449-CA
University of Arizona
Peter F. Ffolliott, Principal Investigator

Published as: Lowe, Phillip O., Peter F. Ffolliott, John H. Dieterich, and David R. Patton. 1978. Determining potential wildlife benefits from wildfire in Arizona ponderosa pine forests. USDA Forest Service General Technical Report RM-52, 12 p. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Mogren, Edwin W., Jack S. Barrows, and Harry B. Clagg. VII-7
1975. Fire ecology in high-elevation forests in Colorado. 3 p.

A study was made to determine vegetative succession following fire, differences in vegetative communities on burned and unburned sites, and relationships of fire intensity and scope to fire effects.

It was found that due to the normally low incidence of lightning fire ignitions, the discontinuous nature and low abundance of fire fuels, and the normally high fuel moisture content in the high-elevation forests of the Colorado Front Range, there has been no great disruption of fuel and vegetation patterns due to the activities of man, either in suppression of lightning fires or the extra load of human-caused fires.

Research Agreement 16-375-CA
Colorado State University
Edwin W. Mogren, Principal Investigator

Potter, Loren D., and Teralene Foxx. VII-8
1979. Ponderosa pine wildfires and urban forestry. Part I--Recovery and delayed mortality of ponderosa pine after wildfire. 33 p. Part II--Success of seeding native grasses after a wildfire. 21 p.

Part I

Recovery of ponderosa pine after fire is complex, but some ecological parameters may be more important than others. Examples are:

1. Survival of fire-scorched trees is dependent on the severity of singeing. It was expected that trees with over 50% of the crown damaged would die. However, over 26% of these trees showed improvement, 53% retained the same classification, and only 21% died in two growing seasons. Smaller trees had a higher rate of mortality than did larger trees, although many saplings in open stands with complete singeing of needles recovered completely.

2. Density of the stand and the resulting competition influenced the recovery of trees; severely stressed trees were unable to compete for water, nutrients, and light. Immature trees less than 4 inches in low-density stands showed nearly complete recovery. However, in stands with over 133 trees per acre, an increasingly high percentage of the young trees declined in vigor. Trees over 4 inches d.b.h. declined in vigor as the density increased above 16 trees/acre.

3. Insects that invade after fire weaken fire-damaged trees. Fifteen months after fire, 12% of the population showed evidence of insect damage. Over 40% of the viable trees showed effects of invasion as evidenced by the production of large amounts of pitch.

Part II

The density of seedlings of the seeded grass was inversely related to the amount of native grass which recovered after the fire. In areas where the pine stand was less severely burned, germination of seeded grasses was considerably less and recovery of native grass was inversely related to the density of surviving trees.

Germination of slender wheatgrass far exceeded all other grass species. In the unseeded plot, Chenopodium species dominated cover and biomass. Western wheatgrass, although 56% of the mix by weight and the second most numerous seed, did not germinate well the first year. Blue grama, spiked muhly, and sand dropseed showed negligible germination.

Research Agreement 16-808-GR
University of New Mexico
Loren D. Potter, Principal Investigator

Ryan, Kevin C. VII-9
1976. Forest fire hazard and risk in Colorado. 249 p. (M.S. thesis).

The purpose of the study was to enhance understanding of forest fire hazard and risk factors. Annual fire records from 1946 to 1973 were analyzed for general trends, and individual fire reports from 10 national forests for the period 1960 to 1973 were used for detailed analysis. A conceptual model of forest fire potential was used to combine hazard and risk in the forest cover types and elevation zones.

The results indicate a definite increasing trend in both lightning and human-caused fires. Human-caused fires tripled during the 28-year study period while area population only doubled.

Fire occurrence was found to be affected by forest cover type, elevation, and aspect. The greatest number of fires and acres burned were in ponderosa pine, but the largest fires occurred in the grass-sagebrush type. Human-caused fires were highest at the lower elevations, with lightning causing more fires at middle elevations. All ignitions were low above 8,500 feet.

Research Agreement 16-468-CA
Colorado State University
Frederick J. Wangaard, Principal Investigator

Ryan, Keith C., and Jack S. Barrows. VII-10
1975. Analysis of fire hazards and risks in the Front Range forests of Colorado. 58 p.

A study was conducted on fires over a 28-year period in the Colorado Front Range. There has been an increase in the average number of wildfires during each 4-year period since 1946. The analysis yielded specific features of fire hazard and risk, and an attempt was made to develop a quantitative rating of fire potential. The model developed assigns equal weight to fire ignition, spread, and magnitude components. The components were normalized on a scale of 100 and evaluated on past forests. A ranking was developed for six forest cover types to indicate fire potential from lightning or human-caused fires.

The model developed will provide insights on fire hazard and risk, but other components must be added to refine the fire potential ratings.

Research Agreement 16-359-CA
Colorado State University
Frederick F. Wangaard, Principal Investigator

Sandberg, David V., Jack S. Barrows, and Jack D. Cohen. VII-11
1976. Analysis of Colorado mountain fire weather. 108 p.

Data for the years 1964-1973 were used to characterize Colorado mountain weather as it affects the potential for forest fires as shown in the fuel complex. Critical fire weather periods were identified and comparisons were made between fuel moisture and weather severity.

A high correlation was found between dry-windy conditions and critical fire weather. Those areas experiencing high frequencies of these conditions had higher fire-weather values and experienced more severe fires. Also, it was found that highly critical surface conditions were associated with high and moderate wind speeds at 500 millibar level.

Research Agreement 16-472-CA
Colorado State University
David V. Sandberg, Principal Investigator

Published as Eisenhower Consortium Journal Series Paper 15, as: Cohen, Jack D. 1976. Analysis of Colorado mountain fire weather. p. 59-65. In: Proceedings of the fourth national conference on fire and forest meteorology. Douglas A. Baker, and Michael A. Fosberg, technical coordinators. USDA Forest Service General Technical Report RM-32, 239 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Sandberg, David V., Jack S. Barrows, and James C. Gibson. VII-12
1976. Prescribed burning in pine forests in the Black Hills. 59 p. plus appendices.

The study was undertaken to determine the number of days in which weather and fuel conditions were proper for successful prescribed burning in the Black Hills. It was found that a substantial number of satisfactory days for prescribed burning would occur in the Black Hills. Burning would be more likely to succeed in October, but May could also provide favorable conditions.

A computer-based methodology was developed to compare trial burning prescriptions to archived weather records of the National Fire Weather Data Library. The methodology provides a fast tabulation of the frequency of satisfactory burning days at any weather station represented in the library.

Research Agreement 16-471-CA
Colorado State University
David V. Sandberg, Principal Investigator

Wagle, R. F., and Thomas W. Eakle. VII-13
1975. Effect of controlled burn on the damage caused by wildfire. 25 p. plus 18 tables.

The effects of wildfire were studied in the Foote Canyon Watershed on the Fort Apache Indian Reservation on previously controlled burned and unburned areas. The results indicate that controlled burning one year prior to the advent of a wildfire will alleviate most of the serious damage to the dominant trees, surface vegetative cover, and the soil organic layers caused by wildfire. Effects of the different fire histories on soil nutrients were also studied.

Additional research needs are identified.

Research Agreement 16-364-CA
University of Arizona
R. F. Wagle, Principal Investigator

Wagle, R. F., and Thomas W. Eakle. VII-14
1976. Evaluation of the fire control, esthetics, and other effects of a "greenbelt" fuel break designed to protect mountain communities from wildfire. 32 p.

A fuel break 10 chains (660 feet) wide was constructed around a developed area east of McNary, Arizona in which basal area was reduced to less than 70 square feet per acre. Permanent paired plots were located, one of each pair within the fuel break and one adjacent to but outside of the fuel break. The fuel break was then burned to reduce surface fuels. Systematic photos of the fuel break and untreated areas were evaluated for esthetic appeal by different groups of viewers.

Surface fuels were reduced by the controlled burning and, together with the open nature of the fuel break and the increased area covered with live green surface vegetation, reduced the fire hazard potential substantially. The intial evaluation of the esthetic appeal of the treatment was low, but should materially change with removal of down fuels and increases in ground vegetation.

Research Agreement 16-352-CA
University of Arizona
R. F. Wagle, Principal Investigator

Wright, Henry A., Francis M. Churchill, and W. Clark Stevens. VII-15
1979. Soil loss and runoff on seeded vs nonseeded steep watersheds following prescribed burning. 20 p. including 2 figures and 3 tables.

Seeding of steep slopes (37% to 61%) after burning reduced soil losses 60% to 91%. Soil loss rates stablilized when cover reached 66%, which took 3 years on unseeded watersheds and 1 year on seeded watersheds. Overland flow stabilized 5 years on unseeded watersheds and in 2 years on seeded watersheds. Water quality was not seriously affected by burning, but it returned to preburn levels within 2 years after seeding. Without seeding, it took 4 years to reach preburn levels.

Research Agreement 16-701-GR
Texas Tech University
Henry A. Wright, Principal Investigator

Additional information on fire effects may be found in the following abstracts: IV-2, IV-5, IV-7, IV-8, and IV-9.